SCHOOL SCIENCE AND MATHEMATICS

VOL. XXVII No. 5 MAY, 1927 WHOLE No. 232

RESOURCEFULNESS, AN UNMEASURED ABILITY.[1]

BY ROBERT O. BEAUCHAMP,
Department of Science, Peabody Demonstration School,
AND HANOR A. WEBB,
George Peabody College for Teachers.

It is a common assertion of modern educators that, *all other things being equal,* an individual who scores high on an intelligence test such as the Binet-Simon, the Otis, the Army Alpha, the Monroe, the Yerkes-Rossy, and other similar tests is more likely to succeed in life because of superior intelligence than one who does not score so high in these tests. The cold, bare fact that the expected success is frequently not attained leads us to the conclusion that the *other things* are not always, if ever, equal.

When the prospective science teacher leaves college where he has had all the apparatus and materials that he needed to perform any experiment or exercise called for in his instructions, and goes to some small place where he must start at the bottom with perhaps only a saw and a hammer, is it his superior intelligence, the direct information acquired at college, or a certain quality of *resourcefulness* which will aid him most, in solving the problems confronting him? Perhaps all three are indispensable, and there is no most important leg of this three-legged stool. But if laboratory resourcefulness is at least as important as any other factor in this case, should we not have some definite method of measuring it? And should we not have data on the correlation of laboratory resourcefulness with certain intelligence tests, and certain achievement tests in science?

This study was undertaken for the following purposes:

[1]Presented November 26, 1926, at the Chicago meeting, Central Association of Science and Mathematics Teachers.

1. To originate a test of laboratory resourcefulness for investigating a hitherto unmeasured ability[2] of high school students.
2. To determine the correlation between this laboratory resourcefulness test, certain intelligence tests, certain achievement tests in physics and chemistry, and past experience in manipulations or situations similar to those given as tests.
3. To determine the correlation between written scores and performance scores with similar groups on the same tests, and the same groups on similar tests.

The Program of General Testing.

In the fall of 1925 sixty-four students of the eleventh and twelfth grades (Demonstration School, George Peabody College for Teachers) were ranked according to their marks in the Otis Group Intelligence Scale, Advanced Examination: Form A.[3] They were divided into two groups of equal intelligence by selecting alternate names for each group. An individual test, the Yerkes-Rossy Adolescent-Adult Point Scale[4] was also given to each pupil. Shortly thereafter the Tests on Laboratory Resourcefulness were presented and completed.

In the spring of 1926 the McCall Multi-Mental Scale,[5] Elementary School, Form 1 was given. Near the close of the school year, the Iowa Physics Test,[6] Series A, B, and C were used to measure the achievement of these pupils who were completing a year's work in physics; the Powers' General Chemistry Test Form A[7] served a similar purpose for the chemistry class.

Thus was measured, first, group and individual intelligence at the beginning of the year, and finally achievement at the end of the year. In between, the tests on resourcefulness were given.

How Resourcefulness Was Tested.

Arrangements were made to test resourcefulness in two ways; first, by actual manipulation of objects, and second, by writing out a proposed procedure, with the objects in plain view. Fifty-six pupils (eight out of the sixty-four who had taken the Otis test having withdrawn for one reason or another) were divided

[2]Probably the first study of resourcefulness by means of test problems was reported by one of us at the St. Louis meeting of the Central Association of Science and Mathematics Teachers, Nov. 25, 1921. See School Science and Mathematics 22:259-267 (1922).

[3]By Arthur S. Otis. World Book Co., Yonkers, N. Y.

[4]From "A Point Scale for Measuring Mental Ability—1923 Revision," by Robert M. Yerkes and Josephine C. Foster. Warwick & York, Baltimore, Md.

[5]By William A. McCall and students. Bureau of Publications, Teachers College, Columbia University, New York City.

[6]By Harold L. Camp. Public School Publishing Co., Bloomington, Ill.

[7]By Samuel R. Powers. World Book Co., Yonkers, N. Y.

into two groups of equal intelligence by selecting alternate names from the ranked list. The test problems were also worked out in pairs, and as subsequent correlations show, were offered in two groups of approximately equal difficulty. Each problem in resourcefulness was attacked with the bare hands by one-half of the students, and with pencil and paper by the other half; each group of students performed individually one-half the problems and set down their proposed procedure in writing for the other half.

Performance was carried out in small booths, in which all necessary apparatus was laid out. The task assigned was printed on a card. An instructor observed the manipulation without comment, and had final decision as to success or failure. A time limit of five minutes was set for each test, preliminary experiments having proved that this was ample.

The *written tests* were conducted by uncovering the apparatus at a signal, the pupil reading at the same instant directions as to the task assigned printed on a sheet. Below these lines he wrote what he would do to solve the problem. A time limit of seven minutes proved to be liberal.

THE TASKS THAT RESOURCEFULNESS MAY ACCOMPLISH.

Forty-two tests were selected from a considerable number by preliminary experiment to establish their practicability. Each could be readily performed in two or three minutes purposeful manipulation. Each places the pupil in a situation where he must exercise ingenuity—must demonstrate resourcefulness—in accomplishing the required result. The field of the tests cover many phases of laboratory work, especially in physics; many, however, are distinctly home problems that might arise any day, rather than technical science.

In the tests that follow, the order is that of difficulty, beginning with the easiest, as demonstrated by the number possessing sufficient resourcefulness to successfully perform the required task.

Tests of Resourcefulness.

Group A, written by 28 students of group X; performed by 28 students of Group Y. The number of successful efforts is indicated following the letters X and Y for each test.

1A. *Given:* Bunsen Burner fastened down; gas supply; matches; short rubber tubes; glass tubes. *Required:* To light the Bunsen burner without moving it. (X, 28; Y, 28)

2A. *Given:* One small piece of wire eight inches long. *Required:* To get the piece of wire in two pieces of approximately equal length with the bare hands. (X, 28; Y, 26)

3A. *Given:* Two bottles of odd shape, nearly the same size; pan of water. *Required:* To find which bottle holds the more. (X, 27; Y, 26)

4A. *Given:* A hammer; one nail; a window without a lock. *Required:* To show how you would fasten the window so that neither sash would open. (X, 26; Y, 27)

5A. *Given:* One glass of water above an empty glass; rubber tube. *Required:* To transfer the water from the full glass to the empty glass below it without moving either glass. (X, 24; Y, 20)

6A. *Given:* Two small mirrors. *Required:* To inspect the back side of the upper front teeth. (X, 19; Y, 25)

7A. *Given:* A mixture of sugar, sand, and iron filings; water; magnet; towel. *Required:* To separate each of the three substances from the other two. (X, 23; Y, 20)

8A. *Given:* Pint can; water; scales; weights. *Required:* To find the approximate difference in the weight of one pint of water and one pint of air. (X, 26; Y, 16)

9A. *Given:* Two bottles containing solutions of salt and sugar respectively; evaporating dish; tripod; wire gauze; matches; Bunsen burner. *Required:* To find out which solution contains sugar and which contains salt without tasting either solution. (X, 14; Y, 27)

10A. *Given:* A string one yard long; scissors. *Required:* To secure accurately a string six inches long. (X, 17; Y, 23)

11A. *Given:* Flask; one-hole stopper; funnel; water. *Required:* To prove that air occupies space. (X, 10; Y, 28)

12A. *Given:* Hare's apparatus, with two liquids. *Required:* To find out which liquid is the heavier. (X, 12; Y, 25)

13A. *Given:* Two sealed bottles of equal size and weight, one filled with water, the other with oil; balances. *Required:* To determine which is oil and which water without opening either bottle. (X, 9; Y, 27)

14A. *Given:* Lens; sunlight; safety match. *Required:* To set fire to the match without using friction. (X, 17; Y, 13)

15A. *Given:* Balances; empty small bottle; flask containing salt solution; flask containing pure water; sand. *Required:* To find out, without tasting, which flask contains pure water, and which salt solution. (X, 13; Y, 16)

16A. *Given:* Two metals riveted together; lighted Bunsen burner. *Required:* To find out which metal expands more on heating. (X, 3; Y, 24)

17A. *Given:* Two wires of different metals; lard; tongs; Bunsen burner; matches. *Required:* To find out which wire conducts heat the better. (X, 15; Y, 6)

18A. *Given:* Bunsen burner; matches; pan of water; flask fitted with one-hole stopper and fine glass jet. *Required:* To fill the flask with water without removing stopper or breaking the jet. (X, 4; Y, 6)

19A. *Given:* Bucket of water; beaker; rubber tubing; shallow pan of water with bell jar inverted in it. *Required:* To fill the bell jar completely with water, without moving the pan. (X, 3; Y, 4)

20A. *Given:* Mounted tuning fork; sonometer with one wire, with slides for shortening and weights for tightening wire. *Required:* To adjust the wire to the same pitch (that is, tone) as the tuning fork. (X, 3; Y, 4)

21A. *Given:* Sand; balances; two bottles of unequal size, the smaller filled with water; towels. *Required:* To pour exactly one-half of the water in the smaller bottle into the larger bottle. (X, 0; Y, 1)

Group B, written by 28 students of Group Y; performed by 28 students of Group X. The number of successful efforts is indicated following the letters Y and X for each test.

1B. *Given:* Basket ball bladder; balances; weights; string. *Required:* To prove that air has weight. (Y, 27; X, 27)

2B. *Given:* Bunsen burner; matches; tripod; evaporating dish; bottle of liquid; wire gauze. *Required:* To discover, without tasting,

whether bottle contains distilled water, or water with a solid dissolved in it. (Y, 24; X, 26)

3B. *Given:* Dry salt; dry sugar; evaporating dish; tripod; wire gauze; matches; Bunsen burner. *Required:* To determine which is salt and which is sugar without tasting. (Y, 23; X, 25)

4B. *Given:* Dark room with one light; mirror; card with printed matter at the farther end of a long box lying horizontally. *Required:* To read the card without moving the box, card, or light. (Y, 23; X, 23)

5B. *Given:* A large iron mortar with a little gasoline in the bottom; matches; paper towels. *Required:* To light the gasoline and quickly extinguish the flame. (Y, 20; X, 23)

6B. *Given:* Strips of several metals, one being iron; iron tacks; magnet. *Required:* To prove which strip is iron. (Y, 19; X, 24)

7B. *Given:* Two strong sticks; loop of string too strong to be broken with the bare hands. *Required:* To break the loop. (Y, 21; X, 15)

8B. *Given:* A rope, with loops on each end, hung over a pulley on a high support. *Required:* To show how you would raise yourself in the easiest manner about two feet from the floor. (Y, 19; X, 17)

9B. *Given:* Small test tube; large test tube; beaker of water. *Required:* To secure the same pitch of whistle from each tube. (Y, 14; X, 22)

10B. *Given:* Shallow pan; water supply; bottle; rubber tubing; gas supply; glass plate. *Required:* To fill the bottle with illuminating gas unmixed with air. (Y, 15; X, 20)

11B. *Given:* Bunsen burner; matches; empty pan; flask of water fitted with one-hole stopper and fine jet. *Required:* To empty the bottle of water without removing stopper or breaking jet. (Y, 11; X, 23)

12B. *Given:* Large graduated cylinder; water; string; two irregular-shaped rocks of approximately equal size. *Required:* To discover accurately which rock has the larger volume. (Y, 17; X, 16)

13B. *Given:* One empty flask above a similar flask of water; two glass tubes; two rubber tubes; two-hole stopper to fit flask. *Required:* To transfer the water from the lower flask to the upper one without moving either flask. (Y, 8; X, 23)

14B. *Given:* Two dry cell batteries; door bell; copper wire. *Required:* To connect both batteries with the bell so that it will ring. (Y, 7; X, 17)

15B. *Given:* One pound of sand; paper towels; one balance (no weights). *Required:* To secure accurately 4 ounces of sand. (Y, 6; X, 17)

16B. *Given:* Lumps of tin and lead; crucible; tripod; triangle; Bunsen burner; matches. *Required:* To find which metal has the higher melting point. (Y, 11; X, 11)

17B. *Given:* Lighted Bunsen burner with cut-off wired open; matches. *Required:* To quickly extinguish burner, and relight it. (Y, 8; X, 9)

18B. *Given:* Electric light bulb; pan of water; pliers. *Required:* To find out whether the bulb is a partial vacuum, or full of air. (Y, 8; X, 6)

19B. *Given:* Balances; sand; paper towels; one 10-gram weight. *Required:* To secure accurately 12.5 grams of sand. (Y, 3; X, 6)

20B. *Given:* Two small strips of wood, with straight edges; hammer; nails; ruler; pencil. *Required:* To show how you would make an accurate angle of 90 degrees. (Y, 1; X, 8)

21B. *Given:* Porcelain dish; ring stand and ring; wire gauze; burette clamp; Bunsen burner; matches; large flask filled with water. *Required:* To arrange the apparatus so that the water might be evaporated safely while you were absent from the room. (Y, 6; X, 2)

Data on Experience.

At the end of each test the pupil was asked two questions: "Have you ever done this or something similar before? Have you

ever seen, heard of, or read of this or something similar before?" Out of the 1309 successful accomplishments of the required task, 896 were based upon some modicum of experience. The quality of resourcefulness, of course, functions in the recognition of the two tasks, past and present, as being similar. Unless the latter is a direct repetition of the former, resourcefulness is necessary in making adjustments to the new conditions.

Is intelligence or experience the most important foundation of resourcefulness? This becomes one of the pointed questions of this inquiry.

Comparisons Through Correlations.

Resourcefulness and Intelligence Compared. If pupils of high intelligence are correspondingly resourceful, there will be a strong positive correlation between the results of the intelligence tests given and the tests of laboratory resourcefulness. Such relationship does not seem to exist. The Coefficient of Correlation (Pearson's formula, the "product-moment" method) between the results of the Laboratory Resourcefulness Test and the Otis Group Intelligence Test is $+.21 \pm .09$; with the McCall Multi-Mental Test the coefficient is $+.04 \mp .09$. Low values such as these indicate that the two things measured are not allied. Although laboratory resourcefulness is undoubtedly an aspect of intelligence, these widely accepted tests do not measure this particular ability.

Correlation of laboratory resourcefulness with the measurements of the Yerkes-Rossy Adolescent-Adult Point Test is moderate, $+.42 \pm .08$. This test consists of twenty divisions involving response to pictures, comparison of weights, memory span for digits, suggestibility, memory for unrelated sentences, comparison of terms, comprehension of questions, definitions of abstract and concrete terms, appreciation of absurdities, analogies, association of opposites, relational test, box test, ingenuity (in measuring water volumes), comparison of capital letters, code learning, ball and field, geometrical construction, reproduction of diamond figures, memory for design. This test, as do the others, measures intelligence; but somewhere within it are tasks that call forth responses based on mental activities more akin to resourcefulness than are the qualities of intelligence measured by the other tests.

Resourcefulness and Achievement in Physics and Chemistry Compared. Resourceful pupils do not necessarily reach the

heights of achievement in physics and chemistry. The converse is also true; pupils of little resource may make a splendid record of achievement in these subjects, as achievement is measured by the standard tests used in this study. The correlation between resourcefulness and achievement is but $+.14 \pm .09$. However desirable the abilities tested by the Iowa Physics Scale and the Powers' Chemistry Test, they do not demand a resourceful mind in the laboratory.

Resourcefulness and Experience Compared. A correlation of $+.60 \pm .06$ shows the benefit of experience in any resourceful act. Very few indeed of the tasks required in the Laboratory Resourcefulness Test had ever been actually performed by students before; few confessed to having done anything similar. Success in the task assigned was often bound up, however, in a recognition of something "seen, heard of, read about," either "this, or something similar." A substantial correlation of this value is evidence of a genuine relationship.

This correlation is not a *strong* value. Resourcefulness is not a mere repetition of experience, but it is founded upon it. An Eskimo would not be able to repair the engine of an automobile, but he could fix rents in its top. Some previous experience is at the bottom of any resourceful performance. In absolutely foreign situations the typical human sometimes does not exercise enough ingenuity to even preserve life. City men become lost in a forest that woodsmen traverse with ease; the mountaineer in turn is lost a few blocks from the depot in a great city. The student with absolutely strange apparatus before him is in much the same dilemma. But add a little experience to a resourceful mind, and wonders will be accomplished.

Intelligence and Experience Compared. Experience provides a particular intelligence that aids in laboratory resourcefulness, but the standard tests of intelligence used fail to measure it. The coefficients of correlation between the experience record and the Otis test is $+.08 \pm .09$; with the McCall test it is $+.03 \pm .09$. There is a significant correlation between experience and the Yerkes-Rossy data, $+.44 \pm .07$, which complements the moderate relation ($+.42 \pm .08$) between that test and the measures of laboratory resourcefulness.

Experience and Achievement in Physics and Chemistry Compared. The experiences upon which resourcefulness in the laboratory is founded seem of no service to the particular achieve-

ments desired in physics and chemistry as measured by the Iowa and the Powers tests. The correlation $+.19\pm.09$ is insignificant. These tests measure abilities gained by experience, it is true, but they are the more formal experiences of the laboratory and the text book rather than the spontaneous experiences which seem to serve the needs of resourcefulness.

Intelligence and Achievement in Physics and Chemistry Compared. The intelligence and the achievement tests used evidently measure decidedly similar qualities of the trained mind. There is substantial correlation between the Otis test and the Physics and Chemistry tests—$+.53\pm.07$. Moderate correlations are found between achievement in physics and chemistry and the measures of the McCall test, $+.35.\pm08$, and the Yerkes-Rossy test, $+.31\pm.08$. This conformity is comforting; it strengthens the thought, however, that resourcefulness is not included in the direct or indirect abilities which tests of intelligence and tests of achievement are able to measure.

Intelligence Tests Compared. The tests used were reasonably consistent in the information they gave concerning a group of approximately 60 high school pupils. The correlation between results of Otis and Yerkes-Rossy tests is $+.43\pm.07$; between the Otis and McCall tests is $+.54\pm.07$. These are substantial values. The choice of tests of intelligence is demonstrated to have been wisely made.

Conclusions.

1. One of the definitions given by Webster for "resourcefulness" is "capability of meeting a situation, rising to an occasion, or the like." If the Laboratory Resourcefulness Tests given in this study really do measure to an appreciable degree the varying abilities of students to meet a situation, or rise to an occasion, then the low and unreliable correlations between these tests and all other tests given to these same students would seem to indicate that the quality of resourcefulness, or at least resourcefulness in the manipulation of simple objects of the laboratory, is not tested to any great extent by these tests.

2. If resourcefulness is really a desirable factor of a student's ability, then we are not justified in measuring him *only* by tests that do not measure this quality.

3. If resourcefulness is really one of the qualities upon which success in life is founded, then we should present more problems involving resourceful activity in our class-room teaching, our

quizzes, examinations and tests. Some of the emphasis placed upon memoriter methods and achievements may well be redirected toward the development of practical resourcefulness in meeting daily problems.

4. If experience is one of the foundations of resourcefulness, then good training in the schools should include many experiences with actual objects, in varied fields of activity, related as frequently as possible to actual situations of practical living. The solution of simple perplexities gives training for more complex dilemmas. What better service may we offer to the coming generation than training to meet resourcefully their emergencies?

"SOFT" X-RAYS KILL GERMS.

"Ultra-soft" X-rays, radiations that occupy an intermediate position between the invisible ultra-violet light that lies above the ordinary visible spectrum and the "harder" X-rays ordinarily used in surgery and scientific investigation, have been found to be a potent means for killing bacteria, according to Dr. W. Schepmann of Berlin. Their existence has long been known, Dr. Schepmann states, but their properties have never been thoroughly investigated, especially as concerns their physiological effects.

Ultra-violet rays kill germs in a few seconds, and they have long been employed as germicidal agents, but their penetration into water is so small that their usefulness has been limited. X-rays, on the other hand, have great penetration, but it takes hours for them to kill bacteria. The ultra-soft X-rays are intermediate in both penetration and rapidity of action. They do not penetrate so deeply as the regular X-rays, but they do pierce liquids far enough for practical purposes, and instead of hours they require only minutes for thorough sterilization.—*Science News-Letter*.

NEW "MICROAMMETER."

An electric current so small that at the pressure and price of the ordinary house lighting current it would cost less than a four billionth of a cent an hour, can be measured with the aid of a new instrument just developed in the standardizing laboratory of the General Electric Company at Lynn, Mass. It is known as a thermionic microammeter, and a current of a ten-millionth of an ampere is sufficient to carry the pointer completely across the dial, while a single division on the scale represents one five-hundredth of this amount.

The instrument will be useful in measuring the minute currents in insulators and radio tubes, but it is stated that the chief application foreseen at present will be in combination with a photo-electric cell for accurate measurements of illumination. At present, the intensity of electric lights, for example, is measured by visually comparing them with another light of standard brightness. The electrical eye, the photoelectric cell, may now replace the human eye in this work, for the cell converts light energy into tiny electrical currents, which may be easily measured with the new instrument.—*Science News-Letter*.

USING CONTRAST IN TEACHING ALGEBRA.

By Joseph A. Nyberg,
Hyde Park High School, Chicago.

Teachers of algebra are well acquainted with the pupil's inclination to eliminate denominators when adding fractions because denominators are eliminated when solving a fractional equation. Thus the sum of

$$\frac{x}{a} + \frac{x}{b} - \frac{c}{a}$$

is incorrectly written as $bx + ax - bc$, because the equation

$$\frac{x}{a} + \frac{x}{b} = \frac{c}{a}$$

leads to $bx + ax = bc$.

This error does not arise during the particular weeks when the class is learning how to add fractions for at that time the notion of eliminating the denominators has not been thoroughly developed. It is only after the chapter on fractional equations has been studied, and when the teacher gives a review lesson on fractions that the teacher finds out that the latter topic needs reteaching. This is an illustration of an "interference bond" wherein the learning of one topic interferes with the retention of an earlier topic. To avoid this trouble some teachers insist that before the denominators be eliminated from a fractional equation, the pupil must first change all the terms to a common denominator. The above equation, for example, would first be written as

$$\frac{bx}{ab} + \frac{ax}{ab} = \frac{bc}{ab}$$

and then a line would be drawn through all the denominators. This may be good practice but the pupils resent it, regarding it just as another one of the teacher's ways of making algebra more annoying than necessary.

Following the general principle of anticipating an error and warning the pupil about it before it happens even for the first time, I prefer to call attention to this possible error when the first fractional equation is assigned. The work would proceed about as follows. First the class reads in the text, either aloud

or silently, the explanation of how a multiplier is used to change a fractional equation into an equation without fractions. After I have answered any questions, some pupils are sent to the blackboard while the others do the same work at their seats. The class then solves an equation like

$$\frac{2x+5}{6} - \frac{10}{x} = \frac{x}{3}$$

using the multiplier $6x$ which is written as a multiplier of each fraction. Then the very next problem that I ask the class to work is:

Add the fractions: $\frac{2x+5}{6} - \frac{10}{x} - \frac{x}{3}.$

The third problem is:

Solve the equation: $\frac{5}{x+3} = \frac{2}{x^2+3x} + \frac{4}{x}.$

and the fourth problem is:

Add the fractions: $\frac{5}{x+3} - \frac{2}{x^2+3x} - \frac{4}{x}.$

The homework for the day would consist of some fractional equations and *an equal number of problems involving the addition of fractions.* Further, the next day's recitation would begin by asking some pupil to come to the board and give a five-minute talk on "The Difference Between Adding Fractions and Solving a Fractional Equation." This talk is given occasionally thereafter by other pupils.

This plan of contrasting certain closely related problems can be used advantageously with many other topics, a few of which will be discussed.

Usually when the class first solves an equation like $5x = 20$, the next few problems are likely to be $4x = 20$, $3x = 18$, $6x = 24$, etc. However, to emphasize that x is found by dividing a certain number by a certain other number, it is well to follow $5x = 20$ with the series:

$20 = 5x,\quad 5x = -20,\quad -5x = 20,\quad -5x = -20,$
$20 = -5x,\quad -20 = 5x,$

Likewise, after solving $ax = b$ the next equation need not be $cx = d$; it is better to contrast $ax = b$ with $a + x = b$ so that the different operations may be clearly

seen. Also, $a + x = b$ should be contrasted with $a - x = b$, with $x - a = b$, and with $a = x - b$. After such distinctions have been brought out the pupil may work a miscellaneous collection in which all the operations are used.

The equation $3x^2 = 48$ may be contrasted with $3 + x^2 = 48$, and this with $3 - x^2 = 48$, with $x^2 - 3 = 48$, with $\frac{x^2}{3} = 48$, and with $48x^2 = 3$. After these equations have been discussed and the pupils called on to state exactly what operations are used in each equation, then a miscellaneous list of equations may again be used.

The work in factoring can easily become so mechanical that the pupil forgets after a time what factoring really means. For example, if factoring $x^2 + 8x + 12$ is followed by some of the same type, as $x^2 + 7x + 10$ and $x^2 + 9x + 14$, the problem soon reduces to: Find two numbers whose sum and whose product is known. This is really only drill in arithmetic. Of course this fact needs to be absorbed; but we can teach much more than this. Thus, following $x^2 + 8x + 12$ with $x^2 - 8x + 12$. emphasizes the importance of the plus and minus signs. Following $x^2 - 8x + 12$ with $x^2 - 13x + 12$ teaches the use of the middle term. Following a quantity like $x^2 - 4x - 12$ with $x^2 + 4x - 12$ again emphasizes the significance of the signs, as does $x^2 + x - 12$ followed by $x^2 - x - 12$. If these quantities occur in widely separated places in the lesson, the contrast is lost. Since errors in factoring are due more to errors with plus and minus signs than to errors in arithmetic, it is the plus and minus signs which should get the most attention.

Again, in order to get practice in something else than the multiplication table, we may begin once more with factoring $x^2 + 7x + 12$ and follow it with $x^4 + 7x^2 + 12$, and follow this with $x^2 + 7xy + 12y^2$, with $x^4 + 7x^2y + 12y^2$ and with $x^2y^2 + 7xy + 12$. Similar exercises may be used when the coefficient of the highest power is not 1.

In the multiplication of binomials by inspection a list beginning with $(3x + 2)(5x + 4)$ and followed by others of the same kind using plus signs in both parentheses is not so good as the following sequence:

$$(3x + 2)\ (5x - 4)$$
$$(3x - 2)\ (5x + 4)$$
$$(3x - 2)\ (5x - 4).$$

From any such problems the pupil can get the necessary practise with the rules for getting the first, middle, and last term. The above sequence, however, is better as it forces attention on the plus and minus signs and prevents too much mechanical work. There is no contradiction here of the axiom that only one thing should be taught at a time; the pupil has already learned the rules for operations with plus and minus numbers.

The rules for squaring a binomial by inspection, as $(3a+4b)^2$, are not so quickly forgotten if the problem $(3a + 4b)(3a + 4b)$ is followed by $(3a + 4b)(3a - 4b)$ and both types used in the same lesson. The fact that one middle term is $24ab$ and the other is $0ab$ emphasizes at least that the middle term deserves full attention. Likewise $(3a + 4b)^2$ should be contrasted with expressions like $(3a - 4b)^2$, with $(3ab - 4)^2$, with $(3 - 4ab)^2$, and with some like $(3a^2 - 4b)^2$.

The review and drill on factoring should not consist of exercises rapidly changing from one type to another with no similarities whatsoever. In review work $x^2 - 4$ may well be grouped with $x^2 - 4x$, with $x^3 - 4x^2$, with $x^3 - 4x$, and with $x^2 + 4x$. Many other groups can also be arranged to emphasize certain important facts. Problems which look very much alike at a first glance and which differ fundamentally prevent mechanical work and lazy habits of thinking.

In the study of radicals, $\sqrt{9\times 11}$ may be contrasted with $\sqrt{9+11}$. Also $\sqrt{a^2b^2}$ may be contrasted with $\sqrt{a^2+b^2}$, with $\sqrt{a^2-b^2}$, and with $\sqrt{\frac{a^2}{b^2}}$. At some place or other in the work, such expressions should be written on the blackboard and the pupils asked to explain what can and what *cannot* be done with them. So much of our reasoning and so many of the teacher's explanations are based on analogies that the pupil can hardly be blamed for assuming that $\sqrt{a^2+b^2}=a+b$ after the teacher has pointed out that $\sqrt{a^2b^2}=ab$. The things that are *not* true need emphasis as well as the things that are true. After learning in a proportion that the means may be interchanged and that the extremes may be interchanged, who can blame the pupil if he assumes that the numerators may also be interchanged?

The contrast between the simplification of $\dfrac{a^2\,b}{a^2\,c}$ and $\dfrac{a^2 + b}{a^2 + c}$

is discussed so fully in every textbook that nothing need be said of it here. In review work, and when the class is being drilled, much can be taught by assigning problems in which cancellation is impossible. And for contrast it is well to use a fraction like

$$\frac{2x^2 - x + 6}{2x - 3}$$

in which the numerator cannot be factored at all so that long division must be used.

In some of the verbal problems there is opportunity to contrast various ideas.

If John has x dimes and $(x + 3)$ nickels it is customary to form an equation from some information about the *value* of the coins, and the teacher must explain the difference between the *value* of the coins and the *number* of coins. This trouble can be partly decreased by working some problems in which the equation *is* based on the number of coins. Thus the following two problems should be worked one immediately after the other:

1. John has 3 more nickels than he has dimes. The value of the coins is $1.35. How many nickels and how many dimes has he?

2. John has 3 more nickels than he has dimes. He has 19 coins in all. How many nickels and how many dimes has he?

Problems of the second kind are frequently used during the first month's work, and the first kind during the third or fourth month. The distinction will be clearer if the equations for both kinds are derived at the same time.

The equations for the following age problems can also be derived in the same lesson rather than studying the first type during the first month of algebra and then basing later work on the second type:

1. John is two years younger than Henry. Six times John's age equals five times Henry's age. Find the age of each.

2. John is two years younger than Henry. Six years from now, nine times John's age will equal eight times Henry's age. Find the age of each now.

Consider the next two problems:

1. A coal bin is l feet long, w feet wide, and h feet high. Write a formula for the number of tons, T, of coal that the bin can hold if 1 ton fills 38 cu. ft.

2. A wall is l feet long, w feet wide, and h feet high. Write a formula for the number of bricks, B, in the wall if 15 bricks fill 1 cu. ft.

The pupil will answer for the first problem $T = \dfrac{l\,w\,h}{38}$ and for the second will write incorrectly: $B = \dfrac{l\,w\,h}{15}$

If the problems are interchanged, the answer for problem 2 will be $B = 15lwh$, and for problem 1, $T = 38lwh$.

This illustrates how much the pupil argues by analogy. He can hardly be blamed for this when we consider how much of the seventh and eighth grade work is intuitive which often means "Guess at the method. You know so little that your guess will very likely be right." To counteract these errors it is well to present situations in which more thinking is required.

A STUDY OF THE CHEMISTRY FOUND IN AGRICULTURAL PERIODICALS.

By Arlee Nuser,

Drake University.

In order to determine the knowledge of chemistry necessary for an individual who is to read intelligently agricultural periodicals, a study was made of three of the periodicals of widest circulation, namely, American Farming, Farm Journal, and Successful Farming. The study included issues of ten years' publication.

The following is a brief statement of the sections into which the study was divided with the results in each case.

1. The chemical principles or groups of principles fell into the following classes, given in order of the frequency of occurrence: Changes of state, oxidation, neutralization, principles involved in study of solutions, chemical changes, definite proportion, ionization, metallic displacement.
2. The chemical topics in order of frequency are as follows: Disinfectants and germicides, fuels, cleaning agents, chemical preparations, solvents, chemical composition; paints, varnish and wax; explosives and inflammable material, acids and their use, drying agents, preservatives, fermentation, bases and their uses, emulsions and colloids, water, bleaching agents, physical properties of various chemicals, reduction of ores, refrigerators, fire extinguishers, filters, dyes and stains, photography, pasteurization, disintegration, theory of the electron.
3. The chemical vocabulary consisted of two hundred and ninety words. One hundred and four were organic substances. Of the one hundred and six inorganic the order of frequency of classes was as follows: salts, oxides, non-metals, mixtures, acids, metals, bases, miscellaneous. The common name is used much more frequently than the purely chemical name of substances.
4. The chronological analysis shows that there is a steady increase in the use of chemistry in agricultural periodicals.

REMARKS ON THE STABILITY AND SPINNING OF AIRPLANES AND PARACHUTES.

By H. Bateman,

Professor of Mathematics, Theoretical Physics and Aeronautics, California Institute of Technology.

In the fifteenth century Leonardo da Vinci pointed out that the attitude of a bird in gliding flight depends on the position of the center of pressure on the wings. If the center of pressure is in front of the center of gravity the bird's tail will tend to drop while if the center of pressure is behind the center of gravity the tail will tend to become higher than the rest of the body.

This principle is well illustrated by simple experiments with model gliders. A rectangular card will turn over and over when falling through the air because the center of pressure is (Fig. 1)

Fig. 1

generally in front of the center of gravity.[1] The rate of spin depends, of course, on the magnitude of the couple and the moment of inertia of the card about a lateral axis through its center. A card of high aspect ratio (ratio of the length of the leading edge to that of an edge perpendicular to it) will spin at a high rate. So also will a card which is weighted along a central line parallel to the leading edge because the additional weight increases the supporting air force and consequently the turning couple, while the moment of inertia about the axis of spin is not much changed.

The spin may be eliminated entirely by weighting the card so as to bring the center of gravity forward so that it is nearly or exactly coincident with the center of pressure. The weighted card can then glide smoothly down to the ground. It need

[1]This phenomenon has been studied theoretically and experimentally by N. Joukovsky. De la chute dans l'air de corps légers de forme allongée, animés d'un mouvement rotatoire. Bulletin de l'Institut Aérodynamique de Koutchino. Fasc. I. 2nd Ed. Moscow. (1912.) 1st Ed. (1906).

hardly be added that the position of the center of gravity of an airplane is of great importance in determining its stability and controllability.

Another principle of great importance for stability is that of the dihedral angle. The use of the dihedral angle was strongly recommended by Alphonse Penaud in his patent[2] of 1876 and is almost universally adopted to secure longitudinal stability, the tail plane of an airplane being set so that its angle of incidence is less than that of the wings.

The principle of the dihedral angle may be simply illustrated by an experiment with a card bent down its center line so that it is shaped like a V. When the point of the V is held upwards and the card is allowed to fall it will turn over but when the card is dropped with the point downwards it will generally fall steadily to the ground.

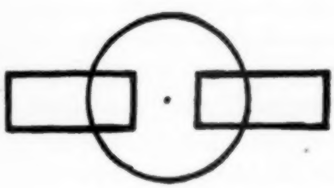


FIG. 2

FIG. 3

A parachute, formed by attaching a weighted thread to the center of a cardboard disc, is very unstable but the instability may be corrected by providing the parachute with flexible wings which will bend upwards and so produce a dihedral angle. (Figs. 2 and 3.) Much may be learned regarding the stability of gliders by model experiments such as those described by Mr. F. W. Lanchester in his excellent books but far more may be learned from an adequate mathematical theory of stability.

[2]Penaud's work on stability dates from 1870. The idea of the dihedral angle is used in a slightly modified form in a staggered biplane with decalage, i. e. an arrangement in which the angle of incidence of the lower plane is less than that of the upper. The staggered convergent biplane is the basis of an inherently stable type of airplane patented by A. A. Merrill (Patent No. 1355990, Oct. 19, 1920).

The year 1911 will be gratefully remembered by many mathematicians as the year in which Professor G. H. Bryan, of the University College of North Wales, published a book entitled "Stability in Aviation" in which he gave an account of some mathematical researches started about 1903 and completed by a few enthusiasts in spite of the lack of experimental data.

This work, so admirably started by Bryan and Williams,[3] has been continued at the aerodynamical laboratories in England and the United States and with the aid of the results of model and full scale experiments has been developed into an elaborate theory which is one of the most important contributions of mathematicians to engineering. We owe the development of the theory largely to the efforts of L. Bairstow, J. Nayler, H. Glauert, R. Jones, J. Case, S. Brodetsky and G. P. Thomson in England and of J. C. Hunsaker, E. B. Wilson, A. F. Zahm, E. P. Warner and M. Munk in the United States.

It was by a happy combination of the results of the mathematical theory and the experience obtained from many daring flights with experimental machines that the late Edward Busk succeeded in 1914 in designing an inherently stable airplane (B. E. 2c).

One inference from the mathematical theory is that an aeroplane of conventional design may be quite stable when flying steadily at its cruising speed but unstable when flying steadily at a speed close to its minimum speed. At this lowest speed the angle of incidence of the wing is generally close to the critical angle α_0 at which the ratio of the lift per unit area of the wing to the square of the speed is a maximum. At angles of incidence above this critical angle the airplane is said to be "stalled" and control is difficult partly on account of the smallness of the forces on the control surfaces at a low flying speed and partly on account of the yawing moment, opposite to that of the rudder, which is introduced when one aileron is moved down and the other one up so as to bank the machine when making a turn.

Either on account of instability or lack of control a stall frequently results in a change of motion in which one wing drops and the airplane goes into a spin. If the height above ground is insufficient for recovery the aviator is frequently killed. Ac-

[3]Theories of stability which were more or less incomplete had been developed by Ferber; Seé and others while Lanchester, Crocco, Harper, Reissner, Brillouin and de Bothézat had made useful contributions.

cording to an article[4] by H. Glauert, the method of recovery from a spin which depends on bringing the rudder and ailerons to their neutral positions and moving the stick forward to turn the spin into a dive, was evolved by H. G. Hawker when flying a Sopwith airplane. The method became well known when Major F. W. Gooden performed a number of spins on an F. E. 8 airplane. The spin soon became a recognized maneuvre in air fighting, being used as a means of losing height rapidly and also as a means of deceiving the enemy.

Some designers have succeeded in turning out airplanes which will not spin and such airplanes are useful for training machines and perhaps for commercial machines. For purposes of war and sport maneuverability is desirable and so designers guard against the dangers of spinning by giving the airplane more control. Consequently many airplanes are provided with large rudders. The subject of control at low speed has been very carefully studied in England and some novel means of improving aileron control have been developed.

Scientists are not content with improvements in design, they wish also to understand and in 1918, Dr. F. A. Lindemann, who is now Professor of Experimental Philosophy at Oxford University, made some scientific experiments on the behaviour of an airplane in a spin. In an important paper,[5] written in collaboration with H. Glauert and R. G. Harris it was shown that a spin is essentially a spiral glide in a very steep path with the angle of incidence of the central portion of the wing greater than a_0. The time for one complete turn about a vertical axis may be about 4 seconds, the indicated airspeed about 55 miles per hour and the radius of the helix described by the center of gravity between 10 and 20 feet. The angle of incidence varies along the span of the wings at a rate which may amount to 1° per foot. This result, which is the key to the scientific explanation of the spin, has been confirmed by experiments in this country, some of which are described in a report by E. P. Warner and F. H. Norton.[6]

We owe the complete elucidation of the spin to the suggestion of Leonard Bairstow that a spin might be imitated in a wind

[4] The investigation of the spin of an aeroplane, "British Advisory Committee for Aeronautics." Reports and Memoranda No. 618. June, 1919.

[5] The experimental and mathematical investigation of spinning. British Advisory Committee for Aeronautics. Reports and Memoranda No. 411. (1918.)

[6] Angles of attack and air speeds during maneuvers. N. A. C. A. Report No. 105. Washington. 1921.

channel by the autorotation of an aerofoil. If a model wing is held in a wind channel so that it is free to rotate about a horizontal axis parallel to the airstream and is inclined to this axis in such a way that the angle of incidence of the central portion is greater than the critical angle α_0, the wing, if once started in rotation, may continue to rotate like a windmill but if the angle of incidence of the central portion of the wing is less than α_0 any initial rotation will be quickly damped out.

The experiment was performed at the National Physical Laboratory, by E. F. Relf and T. Lavender[7] and is often shown in lectures by mounting a wing or model airplane on a spindle which in its turn is so mounted on bearings that it can turn without much frictional resistance. The model is then placed in the draught of a fan and will frequently rotate of its own accord. A student who is interested in the phenomenon of autorotation may perform the experiment himself with very simple apparatus. A light model airplane may be constructed out of cardboard, a cambered wing being obtained by pasting pieces of cardboard together so as to form steps (Fig. 4) and then pasting

Fig. 4

a sheet of paper over them. The wing and tail may with advantage be connected by a thread so as to produce a longitudinal dihedral angle of the type recommended for stability. An axis of rotation making an angle of about 20° with the plane face of the wing and passing roughly through the center of gravity of the model may be marked out by sticking threaded needles into the wing and tail so that they are in line. If now the model is held (Fig. 5) by means of the ends of the two threads T^1, T^2 so

[7] "The autorotation of stalled aerofoils and its relation to the spinning speed of aeroplanes." British Advisory Committee for Aeronautics. Reports and Memoranda, No. 549. (1918.)
Some experiments on the autorotation of bodies of different shapes were made in 1906 by D. Riabonchinsky, "Recherches sur la rotation de plaques symétriques dans un courant aerien et sur la détermination de la pression qu'elles supportent." Bull. Aér. d. Koutchino. Fasc. I.

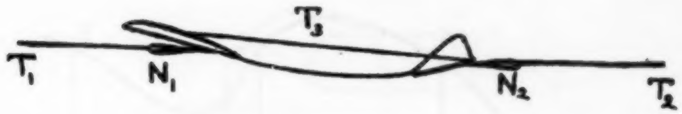


FIG. 5

N_1. N_2 needles. T_1. T_2. T_3 threads.

that its axis is vertical and placed in the downward draught of a fan the airplane will generally spin rapidly without any initial rotation. If the fan cannot be adjusted so as to give a vertical draught the experiment may be tried with the fan arranged so that its wind is directed downwards at an angle of about 45° to the horizon. If now the axis of the model is held in the same direction the experiment will generally be successful. The reason for not choosing a horizontal axis of rotation is that the axis may not pass exactly through the center of gravity of the airplane and in this case a couple due to gravity may check the rotation when the axis is horizontal.[8]

The theory of autorotation may be simply explained by the diagram of Fig. 6, which shows how the force component perpendicular to the axis per unit area of a thin slice varies along the span of the wing. The moment of the forces on the right hand half of the wing is represented by the area CBMN multiplied by the distance of its center of mass from the line CN. Similarly for the moment of the forces on the left hand side of the wing. In order that steady rotation about the axis may be possible the two couples about the axis of rotation must balance and so the center of mass of the area ACBMNL must lie on the central line CN. The reason why the force varies along the span is that the angle of incidence varies. The range of variation of the angle of incidence depends on the angle of incidence and when the curve of type ACB is plotted for different angles of incidence at the center with the aid of the lift and drag curves for the aerofoil, it is more convenient to use abscissae to represent

[8]In adopting the method of demonstration described here I have been helped by a suggestion from Dr. Walter T. Whitney. Diagrams showing the usual arrangement with a horizontal axis of rotation will be found in Bairstow's Applied Aerodynamics, p. 266, and in British Association Report, 1925.

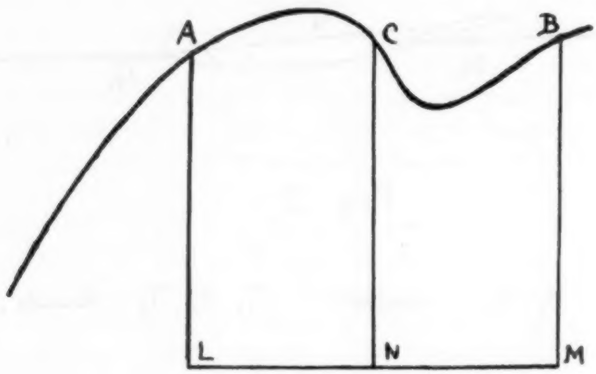


FIG. 6

angles of incidence instead of distances along the span. Assuming that the angle of incidence varies along the span according to a linear law the change simply amounts to a change in scale but the new diagram has the advantage that the same curve may be used for different rates of rotation. To pass from one rate of rotation to another we have simply to alter the distance of the extreme ordinates from the central line. The problem of finding the speed of steady autorotation for a given central angle of incidence[9] is then reduced to the following geometrical problem. Given a curve ACB and an ordinate CN to find a distance LN = NM such that the center of mass of the area ACBMNL lies on the line CN. This problem is only one of a number of geometrical problems of a similar type that are well worthy of study.

It is natural to ask if a parachute can exhibit the phenomenon of autorotation. If we take our circular disc and arrange the flexible wings so that they are not in line (as in Fig 7) and then attach a weight to the center, it is found that on being allowed to fall the parachute will rotate but otherwise fall steadily. The parachute in fact acts something like the propeller of an airplane in a steep dive. At one diving speed the propeller rotates freely without exerting any torque on the engine. This corresponds to the autorotation of the aerofoil. It is interesting to compare the speeds of autorotation of propellers of different pitch with the

[9]. In the case of an airplane autorotation seems to be possible within a certain range of angles of incidence, and in some cases not at all.

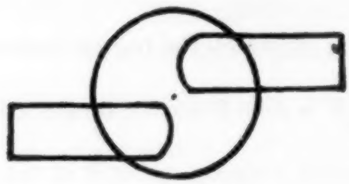


Fig. 7

speeds of autorotation of wings with different central angles of incidence. The torque of a propeller is usually plotted against the quantity $\frac{V}{nD}$ where V is the velocity of the airplane, D the diameter of the propeller and n the number of revolutions per second. The point in which the curve meets the axis gives the

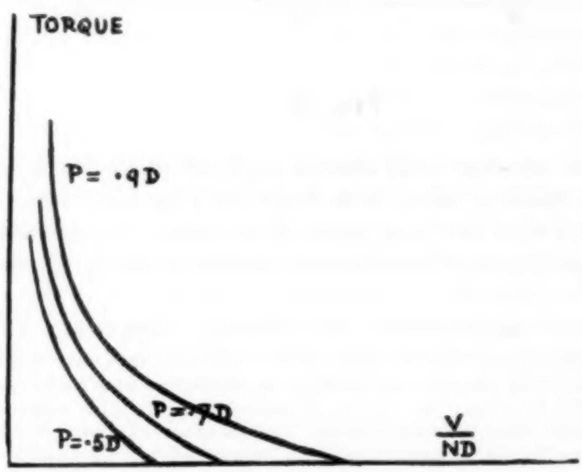


Fig. 8.

value of $\frac{V}{nD}$ for (Fig. 8) which the torque vanishes and autorotation is possible. It is seen from the diagram that this value of $\frac{V}{nD}$ generally increases with the pitch P of the propeller, consequently at a given air speed the propeller of lower pitch will spin at a faster rate. In the case of the airplane wing the variation of

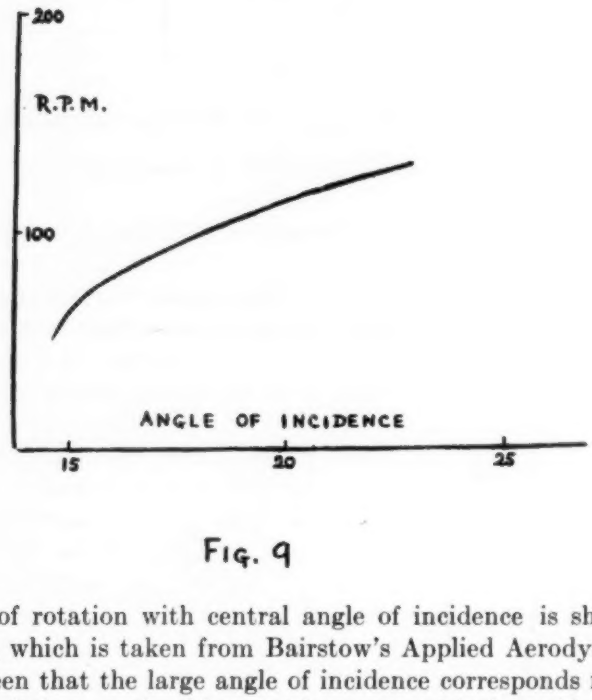


FIG. 9

speed of rotation with central angle of incidence is shown in Fig. 9, which is taken from Bairstow's Applied Aerodynamics. It is seen that the large angle of incidence corresponds roughly to low pitch as we should expect from geometrical considerations.

DETROIT MAINTAINS MUNICIPAL MEDICAL COLLEGE.

The degree of bachelor of medicine was conferred last summer upon 40 students in the Detroit College of Medicine and Surgery who had completed the four-year course of instruction, and the degree of doctor of medicine upon 50 students who had satisfactorily completed one year of interneship or research and had submitted an acceptable thesis for degree. Of the 249 students registered last session, 88 per cent were residents of Detroit. The service rendered by the college, which has been for eight years a unit in the city school system, is steadily increasing. A new six-story building, now under construction, will be ready for occupancy in the spring of 1927.—*School Life.*

AIDS IN TEACHING GENERAL SCIENCE.

By Edward A. C. Murphy,

Utica Country Day School, New Hartford, N. Y.

I hold the object of a course in first year Science to be to help pupils observe accurately and to tell accurately what they have observed; and second, to become acquainted with the world of nature in which they live and to be interested in it.

The kind of pupils that I had, in one class, were those, who on first observation promised to be the least interesting pupils. They were from the Manual Scientific Course, which meant, that besides taking first year Science, Algebra and English, they were to spend the rest of their time in printing, forging, carpentry and other manual subjects. Pupils who had done well up to this point in their school careers in Academic studies, would naturally have been placed in other courses, therefore, if the development of this particular class was good, it would certainly have been at least as good if the youngsters had had a better Academic background.

For equipment, we had access to all the laboratory equipment of a good chemical and physical laboratory. Unfortunately, there was no provision for individual experimentation, but all that was essential for doing exhibition work for the class to watch. We had one of the many excellent and interesting text-books on General Science and a good text-book on Physical Geography, enough copies of both so that each pupil could have one. In addition, there were several authoritative scientific books in our library, "Books of all time," also a number of text-books in chemistry and physics, astronomy and biology. In addition to this, we subscribed to the following magazines: *Guide to Nature, Science and Invention, Popular Science, Popular Mechanics, Scientific American* and a magazine and a school newspaper containing a good deal of scientific material, the *Literary Digest* and *Current Events.* We also had access to the school library and the daily papers.

The disadvantages under which we were working consisted principally of the fact before mentioned, that we had no adequate facilities for individual experimentation; second, that the desks in the school room resembled those in most school rooms and were nailed to the floor in prison-like rows. This I considered a real handicap, as it is difficult to have the necessary atmosphere of freedom in the class-room when pupils are supposed

to sit still in one spot hour after hour. An ideal arrangement would have been movable chairs, so that when anything was to be discussed, we could gather around after the fashion of the Indians in council and have an interesting talk, in which each person could face all the others when he got up to speak.

Certain general features that we adopted in order to carry out what I conceived to be the object of such a course, the bringing out of the ability to tell what had been observed and to acquaint the pupils with the world of Nature in which they lived, were as follows:

Voluntary Home Work.

First, we had only voluntary home work. If, in such a course, home-work were assigned day after day, which the pupils had to prepare, which would mean largely to memorize for reciting the next day, the object of the course would have been defeated at the start, for such a method does not depend upon the initiative of the pupil and soon becomes drudgery.

Drudgery certainly defeats interest, and interest is of primary importance. Instead of compulsory home study, we decided that a record would be kept of any written theme on any subject that a pupil brought in and that he would get credited with that and would be allowed to read it before the class. In this way, the children were stimulated to write about any subject in science which particularly interested them.

Scout Reports.

Second, the Scout Reports played a particularly important part in science, therefore, in a development of interest in the world of Nature and also in the development of ability to observe accurately and report accurately what was observed. The scout report was simply an oral discussion on any scientific subject that had come to the youngster's attention. If he had read in the daily papers of a proposed trip to the moon in a rocket, he would bring that report in and discuss with his classmates the possibility of such a trip and the scientific laws that would govern the ascent of the rocket. If he had seen a bird which he could not identify, he would give a verbal description and try to learn from someone what species it was, and whether it was a resident or migrant, what its habits were and so on. If he had seen, on his way to or from school, the welding of a car track, the brilliant light, the shield to protect the eyes of

the workmen and the sign "Do not look at this light," he would bring it in to class and try to find out from his class-mates or by consulting a book from the library, just what the process of track-welding was. These scout reports were often illustrated by actual objects brought into class. For instance, a home barometer made out of an electric light bulb from which the tip was broken off under water, and the bulb filled with water; a boy who had received a chemicraft set for Christmas did several simple experiments in Chemistry for the class. One who noticed an advertisement in a magazine for a certain kind of tooth paste answered the ad and received a sample tube of paste and some litmus paper. From this developed a study of the effect of acids and alkalis on litmus. Numbers of stones varying in weight from a few ounces to six or eight pounds, were brought in during the year to be identified, dozens of birds' nests, hundreds of flowers, leaves, many curios from all parts of the world which had been collected at home, and a great many experiments, some of them illustrating a principle of scientific law and others magical in nature.

Field Trips.

Another stimulant to interest and accuracy of observation and interest in the world of nature were the field trips. On some of these trips I was able to go with the pupils, but obviously, in most cases it was better to go in groups of from two to six, and this was the method used. For instance, when we were taking up the study of astronomy, each youngster was directed how to find the North Star, then he went out alone at night and drew the outline of the great dipper, the little dipper and Casseopia's chair. These maps were compared and drawn out on the board and corrected and later a number of principal star groups added to them. When we were studying glacial formations, the youngsters were asked to go into different parts of the country, surrounding the town, so that all of the country in our immediate vicinity was pretty well covered by one of the groups. They brought back samples of glacial deposits, striated stone and loess, and made drawings of any such striking examples of glacial action as drumlins, kettle holes and eskers. We made several trips in small groups, looking for birds as the spring came along, and tried to get each pupil to have as large a list of birds that he could identify as possible. On starting, we found that some boys of the class could identify

only the English sparrow, a number knew only the English sparrow and starling and very few could positively identify more than five or six of our native birds, even including the robin and the crow. We were fortunate in being able to make a trip to the college laboratory of Electrical Engineering to see the electrical exhibition there. One group made a trip to Sound Beach, the home of the Agassiz Association, which is about thirty miles from town. We started in the afternoon, walked the last five miles of the distance and gathered enough material for scout reports on trees, the habits of the bees, the life of Agassiz and other things to carry over for several days and form a nucleus which increased the scientific information of all the members of the class, even those who were not able to make the trip.

In addition to the written and oral scout reports, each pupil kept his own experiment book in which was written, with illustrations, the results of the demonstration experiments which were done at the teacher's desk.

The Proper Time.

While the course in first year science was pretty minutely outlined in the "School course of study" and while in a general way I had in mind to touch on certain divisions in the field of science and not get through the year without studying at least a little physics, chemistry, astronomy, biology and physiography, it is obvious that it is also proper that each classes' individual interest should determine to some extent the emphasis on any one division of science. Of course the ideal time to study the eclipse of the moon is when an eclipse occurs, the time to study birds is in the spring, heating plants in the winter and so on. One way we were able to choose which problem to attack was by following the newspapers and current magazines. We were able in this way to strike while the interest was greatest on many scientific problems, which would have been taken up in such a class, but which might have been taken up in a preconceived order in the mind of the teacher and not at the proper psychological time. For instance, one copy of the *Science and Invention* contained a brief account of the life of Leonardo da Vinci, with many illustrations of the various scientific inventions in which he was interested. This led to further inquiry into the life of Leonardo and a remarkable appreciation of the fact that he had anticipated in such a degree many of the

principal discoveries since his time. The newspaper reports of Madame Curie's visit to America being seen by a number of the pupils, brought scout reports, giving the cue to the study of radium, of the life of Madame Curie, and also as much material on radium as we could gather from newspapers, magazines, chemistry books and the encyclopedia. The trip to the home of the Agassiz Association gave the psychological cue to the study of the glacial period and the extensive glacial formations. The fact that Ernest Thompson Seton was writing a series of articles on astronomy which appeared in one of the daily papers led to the study, at that time, of some of the most elementary facts of astronomy. Later on, in the same series of Thompson Seton, there appeared articles on birds, butterflies and flowers. Every day from a dozen to thirty of these clippings would be brought in by various pupils.

Science Clubs.

One of the most important factors in the development of the class work was the Science Clubs. Boys of the adolescent period have a particularly strong gang spirit and therefore will enter a club of any kind with the greatest enthusiasm. Where there is enthusiasm, there is bound to be heightened interest and where there is this interest, we have the atmosphere necessary to obtain good results in Science or anything else. This suggestion to form a club came from a pupil of one of the divisions. When the other divisions heard of this, they of course wanted clubs too. So in a short time, wę had a Science Club in each of the four divisions of boys. Officers were elected, consisting of the chairman, who was the teacher, secretary, librarian, assistant librarian and treasurer. Officers, except the chairman, held office for one month only. No officer could succeed himself. The duties of the secretary were to keep an account of all meetings which were held, once a week, during a regular class period. The treasurer collected dues, bought scientific magazines on motion of the club, had pictures framed, also by motion of the club. The librarian saw each day that the magazines were neatly piled on the table and that the books in the library were in shape. He also encouraged boys to lend any books of scientific interest which they had at home, to the library, and during the course of the year, there were about fifty of those books brought from home and loaned to the library. We adopted this order of procedure: Taking up first

whatever necessary business there was to be transacted; second, scout reports, and then some special scientific topic developed at the suggestion of the teacher or after previous consultation with the teacher, and two or three of the pupils. Later, a simple constitution was adopted.

The question of naming the clubs caused a great deal of enthusiasm and practical discussion. For instance, the boys decided to write to Thomas Edison. This was done and in a short time a photograph of Thomas Edison came with his compliments to the club. The club was immediately named "The Edison Club." It of course became necessary for all the boys to know a great deal of the life and work of Thomas Edison and they did this with more interest than would have been the case if they had been assigned it for home work, for here they had a close interest in the matter and would be obtaining a great deal more than in the perfunctory assignment. By the same process, one of the boys got a picture of Dan Beard and named his club after him. One also was named after Dr. Edward F. Bigelow, President of the Agassiz Association, and one after Louis Agassiz himself. The reason for the latter name was that the boys became interested in searching for glacial formations in the country and while the other classes decided that they would name their clubs after living scientists and not after dead ones, the Agassiz Club thought that Agassiz was such a great scientist that they could not do better than choose his name for their club. His motto, "Per Naturem ad Deum" became the class motto. In addition to pictures of the men mentioned, we secured those of Priestly, Morse, Fulton, Robert Peary, Madame Curie, Ramsey and others. In each case some particular thing had arisen to form the incentive to look into the life of that particular scientist at that time. These clubs met once a week in a regular class period.

The Science Clubs were of tremendous importance in teaching accurate observation and ability to report that observation, because the boys were their own critics and no boy could get by with an inaccurate report with his peers as critics.

The Science News.

A Science Newspaper was also published. This was called the Science News. The Board of Editors from each of the four divisions met with the teacher and assorted the material. This work was again voluntary. There was special credit as a re-

ward for any article handed in, if it was neatly written, regardless of whether it was accepted for publication or not. This paper was first "made up" in long hand and then enough copies run off on the neostyle so that each pupil could have a copy. It was issued according to the announcement on the title page, "every now and then," which in reality meant about once a month. The departments were General Scientific News, the Science Clubs and Jokes. In the latter department were jokes sometimes funny but always about science.

Moving Pictures.

In another class in General Science we used motion pictures to good advantage. We of course had the necessary equipment, a motion picture machine, and a good hall in which to show the pictures. Many of the pictures were very striking indeed. In a general way the plan was to show several reels about each general branch of science studied after the pupils had devoted several meetings to that branch in class. The films were rented from the Pathescope Company and the United Projector and Film Company for about seventy-five cents per reel. The program for the year worked out as follows:

Chemistry—Oxygen, Hydrogen, Carbonic Acid and two reels on Liquid Air.

Astronomy—The Astronomer's Workshop, The Birth of the Earth, The Tides and the Moon, All Aboard for the Moon, The Eclipse of the Sun.

Physics—Air Pressure, Peculiarities of the Air, Through Life's Window.

Physiography—Snow and Ice, Hurricane in Harness, How Mountains Are Formed, Origin of Coal.

Biology—How Life Begins, Why Water is Boiled, Heart and Circulation of the Blood, The House-fly, The Mosquito.

While some of the matter shown in the pictures was no better than demonstration experiments in class, it supplemented or took the place of them when material was not at hand to do them. For instance, the pictures showing experiments with liquid air were quite striking and we were not equipped for doing them in our laboratory. The picture of Priestly's historical experiment with oxygen and a live mouse was good also. On the other hand, some of the pictures showed better than any other method could the subject at hand. The picture of the effect of the moon on the tides and one showing the earth's

rotation on its axis and revolution in its orbit at the same time the moon's revolution around the earth was a perfect illustration of the effective use of motion pictures. Two other splendid films possessing the same educational value in a different field of Science were "The Circulation of the Blood" and "How Life Begins."

THE EVOLUTION OF INDUSTRY AS RELATED TO THE EVOLUTION OF SCIENTIFIC KNOWLEDGE.

By R. E. Rose,

Director, Technical Laboratory, E. I. du Pont de Nemours & Co., Wilmington, Del.

(Concluded)

As a direct outcome of the need for energy we have the enormous increase in production of fuel, coal and oil. The introduction of oil as a liquid fuel in turn has made possible the development of the internal explosion engine, essentially a variant of the old steam engine. We have no space to emphasize the history of the specialized gas industry which is nothing but a modification of the conversion of the latent energy of coal into heat energy by combustion, but I should like to remind you that the use of gas for lighting was the starting point of the development of what is known as the synthetic organic chemicals industry which covers dyes, pharmaceuticals and a number of other miscellaneous bodies which originally came into being because of the availability of coal tar, a by-product of the gas industry.

The chemical industries are a direct outcome of our advance in knowledge regarding the properties of matter when undergoing change in composition. In common with other industries they owe their development not only to this knowledge but also to the fact that the rising standard of living which accompanied man's appropriation of energy other than his own, called for a greater intensity of production than before. The whole group of conditions surrounding chemical reaction became more and more under man's control and at each step forward new industries sprang up.

The whole network of chemical industries is so interwoven that it is extremely difficult to choose a path and follow it without finding one's self proceeding rather in circles. The basic substance of all chemical industry has often been stated to be sulfuric acid and since this acid represents the first industrial use of an extremely ingenious principle we may start there.

Sulfuric acid, sodium carbonate, caustic soda and bleaching powder all came into prominence in connection with the growth of the textile industry in England, which itself was a direct outcome of the harnessing of energy in the steam engine. Sulfuric acid was made by the alchemists and they, rather by rule of thumb methods, discovered that the heating of the fumes from burning sulfur with nitre gave oil of vitriol. This was the parent discovery which led to the great development of the chamber process for the manufacture of sulfuric acid. That process depends for its success on the catalytic action of the oxides of nitrogen. They pick up the oxygen from the air and pass it on to the sulfur dioxide, thus converting it into sulfuric acid. Sulfuric acid, although it has lost its importance as the starting point for the making of soda by the La Blanc process, is still one of the most important chemicals. Enormous quantities are used in purifying petroleum, in making gun cotton, in the manufacture of dyes, indirectly in the making of glass, to mention only a few industries which come very close to us.

The principle of catalysis is also fundamental to one of the modern processes by which man is making himself independent of nature for his supplies of nitrogenous fertilizers. As an outcome of the study of high pressures which was necessary to effect the liquefaction of air, the chemical engineer became more accustomed to working at very high pressures. This made it possible to put on a practical scale the discovery made by Haber, the great German chemist, that previous conclusions regarding the effect of pressures on the rate of combination between hydrogen and nitrogen were not correct. He was interested in this from an academic point of view but actually he started an industry. The union of hydrogen and nitrogen can only be effected at very high pressures in the presence of catalysts. Once having made ammonia this can be converted into nitric acid, again by using catalytic methods. The du Pont Company and others have undertaken this method of nitrogen fixation.

Another scientist who started an industrial development of great importance is Sabatier. He found that the addition of hydrogen to carbon in those compounds which the organic chemist calls unsaturated, can be effected at moderately high temperatures in the presence of nickel as a catalyst. This may seem quite a long way from anything of importance commercially but the chances are that every one has eaten considerable quantities of fats which have been processed by the

method developed as a result of Sabatier's work. Cottonseed oil happens to be unsaturated. Treatment with hydrogen in the presence of nickel saturates this and it ceases to be a liquid and becomes a solid at ordinary temperatures. The housewife knows it as Crisco. It is an admirable food. This same process gives us substitutes for turpentine made from naphthalene.

On paper it is easy to write an equation showing the conversion of carbon monoxide into methyl alcohol by the addition of hydrogen. Actually this is a reaction that has been carried out only very recently as a direct consequence of our mastery of high pressures and catalytic methods. Methyl alcohol is made in Germany, and will be made in this country, by such a process. You will suggest that methyl alcohol is probably not a substance of great importance but actually it is used in a great many ways indirectly. The tooth paste you use has very likely been flavored with methyl salicylate and this is made from methyl alcohol and salicylic acid, both artificial products now. The methyl salicylate is identical with that obtained from the wintergreen plant. Methyl alcohol gas, if mixed with air or oxygen, forms an explosive mixture. It might therefore be used as an automobile fuel if it were cheap enough. If the interaction between the oxygen and the alcohol is conducted in the presence of platinum acting as a catalyst, there is no explosion but a continuous heating of the platinum. The product produced is formaldehyde and formaldehyde is one of those modern substances which have become essential in a great many ways unsuspected by any but the chemist. For example, formaldehyde interacts with phenol. The interaction is a very complex one and is promoted by alkalies. The products resulting vary anywhere from fairly mobile liquids to extremely resistant solids. In fact, that was just the trouble with the discovery from the industrial standpoint; it was impossible to control it. Then it was investgated by one of our most ingenious industrial chemists whose eminent success as an industrialist is the direct outcome of his appreciation of the value of fundamental knowledge, Dr. Baekeland. In his hands the reaction was so controlled as to give us the remarkable artificial resin, Bakelite. This is being used more and more wherever small parts have to be molded which are to be resistant to atmospheric and other conditions or which are not to conduct electricity. The ordinary man comes into contact with Bakelite most probably in the form of the mouthpiece for his pipe since this material makes an excellent

substitute for amber, but if you look into delicate mechanical equipment of all sorts you will find very frequently that some essential part is a moulding of Bakelite.

Among the many crude products available to the industrial chemist is cotton, the purest natural form of cellulose. This has been used by him to produce a new fiber for the first time in human history. Rayon is made by treating cellulose with caustic soda and carbon bisulfide or ammonia and copper or sulfuric and nitric acids. The product differs slightly, according to the method of manufacture, but essentially it is a highly lustrous fiber which is now so well known as to need no description. The industry is increasing in importance with astonishing rapidity and already the annual production runs into more than 100,000,000 pounds. The first chemist to attempt the industrial development of artificial silk went bankrupt, which is frequently the fate of the chemist, even one who has a sound process, because of the difficulties of putting this on a commercial scale. From cotton we make the best propellent explosive known, gun cotton. Gun cotton is cotton which has been nitrated until it has taken up all of the nitric acid groups which can be caused to go into the molecule. If it is less highly nitrated and mixed with camphor and other low melting solid bodies, it forms the material known as celluloid and this is an article of very obvious commercial importance as one can see from viewing the exhibits in the department stores at about Christmas time, as it makes an admirable plastic which can be pressed or turned, cut and decorated in a variety of ways. Nitrocellulose, when dissolved in organic solvents such as butyl acetate, makes an excellent lacquer, which is displacing the older paint and varnish in a great many applications. Actually, then, the automobile painted with Duco is protected by a coat of cotton.

Artificial silk can be made in sheets. It is then sold under the trade name of "Cellophane" and makes an ideal material for wrapping fancy small articles since it is transparent and yet dust-proof.

Instead of making nitrocellulose, it is possible to make acetyl cellulose, a new artificial silk which seems to promise as much in its way as rayon did.

Cotton is not water-proof but when it is turned into nitrocellulose and mixed with castor oil it will form a sheet resembling but really very unlike leather. A great many artificial leathers,

as they are called, (a very poor description of the material) are on the market.

Celluloid, apart from being so useful for the making of pretty toilet articles, is the background for the film industry. Every week 60 million people go to the movies and see life as represented by the shadows cast by deposited metallic silver in a gelatin medium on a nitro-cellulose film. In this way a chemical product obtained from cellulose has affected the mode of living of the population mightily. The Eastman Kodak Company, who are the largest producers of photographic products, including films, in this Country, are also, you will be interested to know, the third largest spenders for research, being exceeded only by the two gigantic corporations, the American Telephone and Telegraph, and the General Electric Companies.

By the processes of nature, vegetable matter is converted into coal. Coal, first used for the sake of the energy stored in it, is the parent substance of a number of chemical industries. The first of these is the distillation of coal to produce coal gas. This is not a process that we can follow accurately in terms of the chemical changes occurring; it is more or less empirical. Its value lies in the conversion of a solid fuel into a gaseous one. The production of gas has been supplemented very largely by the conversion of the remaining coke into water gas by blowing steam over it. In the last few months we have started to hear a story of a process which may become of vital importance to us. It is already practiced industrially on a small scale. This is the treatment of bituminous coal under high pressure with hydrogen. Under these conditions the bulk of the coal is rendered liquid and from the product a material similar to gasoline or petroleum can be recovered.

In the making of coal gas coal tar is produced and this celebrated material is the substance underlying the making of dyes, pharmaceuticals and perfumes. The most complicated of all organic chemical industries is that of making dyestuffs. The coal tar is first purified by physical methods and then the fractions obtained are converted into intermediates, colorless bodies which, when suitably united by methods discovered in the research laboratory, give us the brilliant modern dyes that are so much faster than anything we ever had before. There is no more fascinating chemical laboratory on a mammoth scale than the dye plant. The development of this industry as related to the scientific discoveries on which it is based, I have tried

to trace in an article which appeared recently in the Journal of Chemical Education.

Our bodies are the most complicated mass of sensitive organic compounds in existence. As such, the way they function can be influenced very largely by small quantities of materials introduced into our systems. This was just as well known to the witch doctors of our early history as it is to us today but the difference is, that with the growth of scientific understanding the guesses of the witch doctor are replaced by the certainties of modern prophylactic agents made by the great pharmaceutical houses such as Eli Lilly, Mulford, Park Davis. The bulk of pharmaceuticals are made just as dyestuffs are, from coal tar. Kolbe, in 1876, dicovered that when phenol was treated with caustic alkali and carbon dioxide under pressure, salicylic acid was produced. This has meant that salicylates have become cheap medicinals instead of our having to depend on the small quantities available in the wintergreen plant. Analgesics are made from aniline. Adrenalin is made from dihydroxy benzene, chloracetic acid and menthyl amine. This substance is the first of the secretions of the ductless glands to yield the secret of its composition to the organic chemist and in consequence it is manufactured comparatively cheaply in any quantity demanded. There can be no more fascinating problem than that which has been set the chemical research laboratories of the Mayo Clinic in Rochester, Minnesota. They propose isolating the principle of all the ductless glands, studying them until their constitution is known and then devising means for their synthesis. As long as this kind of work goes on we may be sure that our pharmaceutical industries will spread and that they will become increasingly valuable to all of us.

While the quantities of any drug used in any individual case are usually small, the aggregate is sometimes very large and thus the money value of the industry is quite important although one might think it too small to be worth the interest of the industrialist.

Coal can be converted into coke which is nothing but the nonvolatile residue left when coal is distilled. Coke is extremely inert except for the fact that it will burn. However, if it is heated in the electric furnace with lime, calcium carbide is produced. This discovery goes back to the work of Henri Moissan. Calcium carbide reacts vigorously with water to produce acetylene. This is the reaction upon which is founded the Air Reduction

Company, a highly successful corporation who handle acetylene for welding. It is used for this purpose because the oxy-acetylene flame gives us extremely high temperatures, high enough to enable us to weld very infusible metals. This Company became interested in the production of hydrogen cyanide for use in the citrous fruit groves in California. This part of the Company's enterprise was not as successful as the rest. It was made successful by a most ingenious discovery. Sodium cyanide has to be treated with sulfuric acid to liberate hydrocyanic acid speedily enough to destroy scale. Hydrocyanic acid itself is not altogether satisfactory, being a liquid. However, calcium cyanide is admirably suited to liberate hydrocyanic acid rapidly in the presence of water. It does so, even when it is exposed to the moisture of the atmosphere. But calcium cyanide, according to the text book, could not be made in a permanent form. It can be very easily made by the simple process of allowing calcium carbide to interact with liquid hydrocyanic acid, known to the readers of detective stories as prussic acid, a deadly poison.

From calcium carbide a number of other products can be made among which, perhaps the most important is acetic acid, formerly available only by the fermentation of alcohol or by the distillation of wood. From acetic acid we can make acetone, which is a solvent used in the production of nitrocellulose lacquers and nitrogelatin explosives. Here again we encounter the characteristic modern method in chemical development, the utilization of extremely simple abundant materials and their conversion into products otherwise obtainable from less secure sources of supply. Acetic acid, acetone and methyl alcohol and all their derivatives can be made, as I have said, from lime, coke, water and air.

If calcium carbide is heated in an atmosphere of nitrogen it forms calcium cyanamid. This is one of the principal methods by which the nitrogen of the air is fixed for use in fertilizers. It is practiced by the American Cyanamid Company.

The use of the electric current was the first method making possible the control of atoms by reason of the electric charges which they carried. In other words, the electric current, being an electronic stream, enabled us to influence the electrically charged radicals of compounds in solution. Electrolysis is a major chemical industry. The Aluminum Company of America produces aluminum by conducting an electric current through

a fused aluminum salt in which aluminum oxide is dissolved. The making of this metal electrically was possible but could not be made commercial until Hall, a young American, made the discovery of the solubility of aluminum oxide in cryolite.

Magnesium is another metal produced electrolytically and one wh ch is gaining rapidly in industrial importance. The alloys of magnesium, especially with aluminum, are already very important because of their great strength combined with extreme lightness. They enter into the making of aeroplanes and light cameras, to mention but two of the many uses. As magnesium becomes more important it becomes cheaper because it is a general law that the more any substance is used the more cheaply it can be produced, provided the source of supply is not restricted. Few of you perhaps will realize that the alkali metal, sodium, is produced quite extensively for the use of the chemical industries. Sodium, a soft metal which reacts with moisture violently, would seem to be a very difficult product to make. In fact, it did require great ingenuity on the part of the electro-chemist to succeed in isolating this element. Now it can be bought for 27c a pound. A great deal of it is made in Norway. The interaction of sodium with ammonia produces a compound, sodamid, and this is the key to the success of the synthetic indigo industry. These electro-chemical industries are likely to become increasingly important as we learn more of the characteristics of the alloys of the metals which I have mentioned and also of calcium.

Electro-plating is a chemical industry. By it nickel, silver and gold are deposited on surfaces to which they will adhere, thus making silverplated ware, for example, the standard in all households, accessible to all, while so long as the covering of a base metal with silver depended on the old process of burnishing, even silverplate was too expensive for any but the rich. The electro-deposition of metals from a bath is also an important part of the metallurgical industries, serving for the purification of copper, the recovery of tin, and recently for the making of iron.

Iron is a metal which has been used for a great many years but its production was the result of practice and was essentially an art. With the coming of scientific methods we have found much better means for controlling the characteristics of iron by adding small quantities of impurities, the impurities being there to give just the properties we want. In this way we have control

of a whole range of iron carbon alloys, the different grades of steel. Then we have found that the addition of other metals to steel confers very valuable properties. Thus manganese steel, one of the most important alloys, discovered in 1888 by a very young Englishman, Sir Robert Haddfield, is extremely tough and on that account it can be used in high speed machinery such as the automobile engine. It can be used wherever fracture must be avoided, again in the framework of the automobile. A piece of manganese steel can be bent double like a rubber hose without fracture while a carbon steel will snap long before it is bent as far as that. Iron with carbon gives steel. Carbon is very nearly related to silicon which means that it has somewhere near the same arrangement of electrons in its outer shell. Silicon in steels has to be avoided but an iron silicon mixture has very different properties from any other grade of steel. The principle of electro-magnetic induction is fundamental to the conversion of mechanical into electric energy. The transmission of electrical energy is economical only if the voltage used is very high. In order to use the current after it has been transmitted it must be transformed. In the process of transformation there is the chance for the production of induction currents and eddys in the framework of the transformer. Silicon steel does not build up these currents; a very minor point you will say, perhaps, but the use of this alloy in the transformers at present operating in the United States saves nearly $1 to every inhabitant of the Country per year, quite a saving, you will admit.

Nickel is a very new metal. We are only beginning to investigate its alloys. Already we find that nickel-iron offers extremely little resistance to magnetic waves. By using permalloy, one of these nickel steel mixtures, a submarine cable can be made to carry six times as many messages in a given time as it could if its sheath were made of the old material.

Chromium steels are exceedingly hard. The chromium alloys offer us some relief from the menace of corrosion, giving us stainless steel. Alloys of tungsten, iron and chromium are so extremely hard that tools made of them are still capable of cutting even when the speed of the operation causes the chisel to become red hot.

Molybdenum also promises much in the field of alloys. A mixture of 60% cobalt, 22% molybdenum, 11% chromium, 2% manganese and 3% iron is so hard that tools made of it can be operated at a bright red heat without softening. This is

known commercially as "Stellite." Vanadium, in a steel, increases the durability of a tool under heavy working conditions so that it also has found its place in the making of high speed tool supplies. The importance of such resistant metal mixtures can be realized from the fact that modern cutting tools run at from 250 to 500 ft. per minute which is 10 to 20 times the speed possible with any grade of steel containing only carbon.

Cobalt, also a newcomer in the field of metallurgy, is already giving us some extremely valuable mixtures. When cobalt is alloyed with steel in certain proportions the alloy becomes magnetic and holds its magnetism. The cobalt steel called "Permanite" is superior to tungsten steel as a material for the permanent magnets of magnetos and other apparatus subject to powerful de-magnetizing influences.

There is no end to the subject of modern metallurgical advances. The more we learn of metals the easier it is to make new combinations, but given the possible number of metals, the number of alloys is infinite and the variables are so many that there is no way of calculating before hand just what properties an alloy will have. This makes success slow but it is none the less sure and it is all the surer as our knowledge increases.

Before leaving the subject of metallurgy I should like to draw your attention to a process which is making a great many metals cheaper for us. It is a process discovered by a woman who reaped no benefit from it because it was too advanced for the mining engineers of her time. If a sulfide ore is ground up with sand, or other quartz-like matter of the gangue, the sulfide is heavier and therefore has a tendency to sink sooner. The difference, however, is not sufficient when one bears in mind that the sulfide is the smaller proportion of the crude ore, to allow of any separation. If, however, certain substances are added to the water in which the ore is agitated and the agitation is carried to such a point that air is forced down into the mixture, it is found that the heavy sulfide ores, owing to the condition of their surface, hold the air bubbles while the gangue does not. In this way the mean specific gravity of the sulfide and air bubble is sufficient to cause the ore to float from the gangue. Flotation is practiced on an enormous scale, especially in the copper mining industry and the chemist has been called upon to furnish all sorts of materials to effect flotation.

The last century has seen a tremendous growth in human

evolution. The evolutionary curve has been changed altogether by man's conscious effort to control his surroundings. From the day when he discovered the use of fire he started out to beat all other creatures because of his control of energy. However, he did not make extraordinary strides until he learned the value of quantitative research. That is the basic feature of our industries. What the next years will bring we have no means of telling. How can we say what will come of the new agent placed at our disposal by the magnificent work of Dr. Coolidge. I advise you, if you have not already done so, to read his account of his new tube, published in the Journal of the Franklin Institute. Essentially he has found a way of producing enormous quantities of free electrons outside the vacuum tube. These electrons have an incredible effect. In many respects they seem to be the most violent chemical reagents we have yet found. Acetylene is converted almost instantly but without explosion, into a material which refuses to dissolve in acids or alkalies. Flesh is destroyed in a moment and cotton, when exposed to the radiation for 10 seconds, is changed without being heated, to the extent that one might expect from an exposure to sunlight for a year or two. What will come of this we cannot guess. If we allow ourselves a certain enthusiasm, which is warranted if we follow the curve of the evolution of man's control of energy and see how steeply it is rising, then we may expect that before so many generations are passed we shall control the unfathomable resources of atomic energy in which case we shall be able to do anything calling for energy without any question of the expense of the source of supply.

Then will science have introduced the material millenium. But I feel that the advance of man's mental reaction to these discoveries is not keeping pace with the discoveries themselves. It is only a few who appreciate the meaning of science. It is only a few who understand what the men of genius have turned over to the men of industry. In order to safeguard the future and make the evolutionary process worth while, if we are right in guessing what is worth while, then we must educate the mass of humanity and that is where I feel the teacher is all-important. Unless the teacher can do for the mind what the scientist has done for matter the outcome is uncertain. I have enough faith in humanity to believe that the danger which is quite obvious in acquiring too great a control over energy, will be offset by the growth of human restraint coming of enlightenment and I believe that it is the

schools from which that enlightenment will come. Therefore, I say to you, that your responsibility is the greatest faced by any class at present active among the race of men.

NEED FOR PURE SCIENCE.

American science needs to concern itself more with fundamental research than it has done heretofore. No country in the world has made such progress in applied science, but our record in pure science is not so flattering. Since 1900, when the Nobel prizes in physics, chemistry, and medicine were inaugurated, 76 awards have been made. Of these, 24 went to Germany, 11 to England, 10 to France, 6 to the Netherlands, 5 to Sweden, 4 to the United States, 3 to Denmark, 3 to Switzerland, 2 each to Austria, Canada, Italy, and Russia, and 1 each to Belgium and Spain. On the basis of population, the Netherlands, Denmark, Sweden, and Switzerland, received one to every million inhabitants; Germany, one to every two and one-half million; Austria, one to every three million; England, one to every three and a quarter million; France, one to every four million; the United States, one to every twenty-nine million.

This is the situation despite the fact that we have vastly more students in colleges and universities in proportion to the population than has any other country in the world. The difficulty seems to me twofold; we are not laying enough emphasis on pure science in proportion to our emphasis on the applications of science; and we are not stimulating and training an adequate personnel in scientific research.—W. M. Jardine, Secretary of Agriculture, at Yale University.

PLAYER ROLLS YIELD SECRETS.

How study of player piano rolls will give the secret of the marvellous effects produced by the great pianists has been studied by Dr. Guy M. Whipple, director of the National Intelligence Tests.

Comparison of rolls of the great players with the original score will indicate just where and how they deviated from the score to obtain their effects. Such analysis holds great possibilities for piano students and teachers, Dr. Whipple believes. He points out that although the player piano is so perfected that the artists themselves admit the accuracy of the reproductions the piano roll does nothing but control the time relations or the intensity of the piano hammers or the pedals. Hence interpretation is all a matter of time or intensity.

"You strike a key at a certain time with a certain force," he says, "hold your finger there a certain length of time, push the pedals down at a certain time and let them up at a certain time; that's all the mystery there is about the piano playing of the great masters of the key-board." —*Science News-Letter.*

ON A MISCONCEPTION OF THE RELATIVITY OF TIME.

By Luise Lange.

In this paper we propose to discuss a misconception on Relativity which has found entrance into the scientific and semi-scientific literature particularly of Germany, namely a fundamental misinterpretation of the relativity of Time.

The mathematical theory of relativity, so these authors claim, implies that for two observers moving past each other a clock at the place and moment of their encounter indicates two different times. In the words of one of their foremost exponents: "We have to face the fact that this theory not only admits but demands that two relatively moving observers would find on one and the same clock both by sight and touch different positions of the clock hands. E. g. that the same clock shows to the one man's eye and hand 10:00 while at the same moment (that is at the moment of passing it) the other one would see it at 7:30; that again for the second one his own clock shows at the same moment 10:00, while the first observer sees it at 7:30."[1] Another author states the same view in a more general form: "The theory is logically possible only if one grants that processes or states of a 'thing' perceived as real by one observer need not be real also for another one, though he be equipped with the same senses and cerebral functions, as soon namely as both observers are in motion relative to each other."[2]

Though united in regarding this result as a direct consequence of the theory the various authors and philosophical schools differ widely in their attitude towards it. One group, the "Positivists" or "Phaenomenalists" accept it enthusiastically as an exact, mathematical proof for their own metaphysical doctrine; (a doctrine closely related to Berkeley's sensationalism or "solipsism" which regards as the only reality that which is perceived, the colours, smell, "apparent" size and form of things, not however any "objects" existing independent of the perceiving subject.) Other authors on the contrary, styling themselves as Kantians or just as advocates of "common sense," seize this result as an opportunity to denounce the utter absurdity of Einstein's theory, outwitting each other in devising clever exam-

[1]J. Petzold, Die Stellung der Relativitätstheorie in der geistigen Entwicklung der Menschheit, Dresden 1921, p. 64.
[2]K. Vogtherr, Wohin führt die Relativitatstheorie? Leipzig 1923, p. 40.

ples to demonstrate it more drastically: Replace the "clocks" by human beings; then two people might be thought of as moving past each other each of whom is in his own experience an old man while appearing, nay while *being*, for the other one an infant.[3] Or worse, people who in their own world have been dead and buried are still seen and felt alive by observers passing their world with sufficient velocity.[4] Or think of placing a bomb into the clock with a time-ignition adjusted so that it will explode when the clock hand reaches the position 9:00, then, according to the above illustration, at the moment when the two observers pass each other the clock has already been annihilated for the one while for the other it is still in perfect order; and if now the latter could quickly remove the bomb still unexploded for him, the clock which for the first observer's perception was blown to pieces may continue to exist indefinitely for the other one, etc.[5] And with such and similar arguments these authors try to convince Einstein that he had better withdraw his nonsensical theory, and to persuade his followers that they have underfallen a spell of crowd-psychosis.[6]

We now want to show that, no matter what revolutions in our concepts of space and time the theory of relativity may have brought about it is wholly innocent as regards the above fanciful stories. That it neither demands nor even admits the dependence of sense perception on the relative state of motion of the observer.

Let us recall the basic situation with which it deals:[7] Two systems S and S′ move relatively to each other with velocity v,—say with their x and x' axes gliding alongside each other. Each is thought as fitted with a set of ideally accurate clocks placed at measured distances and with observers next to these clocks. When stations A$(x=0)$ and A′ $(x'=0)$ pass each other observers O and O′ at those places set their clocks on $t=t'=0$; and moreover at the same moment they synchronize the set of clocks in their systems as follows: from $x=x'=0$ at $t=t'=0$a light-signal is sent out and observers at stations x and x' are instructed to set their clocks on $t=\frac{x}{c}$, $t'=\frac{x'}{c}$ respectively on

---

[3]K. Vogtherr, op. cit. p. 50.

[4]Ibid. Also more elaborately worked out by E. Gehrcke, Die Relativitätstheorie, eine wissenschaftliche Massensuggestion, Berlin 1920.

[5]K. Vogtherr, Ein neues Uhrenparadoxon, Naturwissenschaftliche Wochenschrift, Vol. 37, 1922.

[6]See the title of E. Gehrcke's paper quoted before.

[7]The first part of the following exposition is to some extent repeated from a paper by the present author appearing in the last January issue of the Amer. Math. Monthly.

receiving the signal. (This method gives expression to the principle of the constancy of the velocity of light for all systems, a principle which in Einstein's first conception of the theory (1905) was of the nature of a postulate untested by observation; the later computations on the orbits of binary stars by De Sitter, (Physikalische Zeitschrift 1913) in conjunction with Michelson's result furnished the experimental basis for this postulate.)

Of two such systems the theory of relativity states: *If an event is observed in system S to occur at place x and at time t, then the same event is observed in system S′ to occur at place x′ and time t′ where these two sets of magnitudes are connected by the following relations:*

$$\text{I} \quad \begin{cases} a) & x' = \dfrac{1}{\sqrt{1-\dfrac{v^2}{c^2}}}(x-vt) \\[2ex] b) & t' = \dfrac{1}{\sqrt{1-\dfrac{v^2}{c^2}}}\left(t-\dfrac{vx}{c^2}\right) \end{cases} \qquad \text{II} \quad \begin{cases} a) & x = \dfrac{1}{\sqrt{1-\dfrac{v^2}{c^2}}}(x'+vt') \\[2ex] b) & t = \dfrac{1}{\sqrt{1-\dfrac{v^2}{c^2}}}\left(t'+\dfrac{vx'}{c^2}\right) \end{cases}$$

(S′ is assumed to move in direction of positive x relative to S.) This system of equations, the so-called Lorentz transformation, thus replaces the old Galileo transformation of classical mechanics:

$$\text{I)} \quad \begin{aligned} x' &= x-vt \\ t' &= t \end{aligned} \qquad \text{II)} \quad \begin{aligned} x &= x'+vt' \\ t &= t' \end{aligned}$$

to which it is seen to reduce if v is sufficiently small in comparison to c.

What as regards the relativity of time follows from these equations?

Observer O′ at A′ ($x'=0$) who passes station A($x=0$) when both clocks C_o and C_o' show $t=t'=0$ (e. g. 12:00) arrives at a station B($x=vt_1$) when the clock C_x at that place shows $t=t_1$, (for this is the meaning of S′ having a velocity v relative to S). Hence, according to equation I*b*) his clock C_o' shows then and there:

$$t' = \frac{1}{\sqrt{1-\dfrac{v^2}{c^2}}}\left(t_1-\frac{v.vt_1}{c^2}\right) = t_1.\sqrt{1-\frac{v^2}{c^2}} \quad ; \text{ that is } \textit{less} \text{ that } t_1.$$

If e. g. we choose $\sqrt{1-\dfrac{v^2}{c^2}}=\dfrac{1}{2}$ and $t_1=1$ the situation is as fol-

lows: O′ passes O when both their clocks show 12:00; he arrives at station B($x=v$) when the clock there shows 1:00, while his own clock has gone on only to 1. $\frac{1}{2}$ (to 12:30).

Hence observer O_1 at B($x=v$) could say: Your clock goes twice slower than those in our world; for the time elapsed between your departure at A($x=0$) and your arrival at B($x=v$) is one hour according to S−time, while only one half hour according to yours.

Answers O′: "This conclusion drawn from the comparison of our clocks does not have absolute validity. *Though we both agree that your clock shows at this moment $t = 1$(1.00) and mine $t' = \frac{1}{2}$ (12:30) and though I equally agreed with observer O at A ($x=0$) that both our clocks showed $t=t'=0$ (12:00) when we parted, I yet claim that the clocks in your world go twice slower, not faster, than mine.*

How so?

When I left A at $t'=0$ your place ($x=v$) was relative to S′ at $x' = \sqrt{1-\frac{v^2}{c^2}}\cdot v = \frac{1}{2}v$, (From equation IIa solved for x'); and when a clock in S′ at $x' = \frac{1}{2}v$ showed $t' = 0$ your clock showed then and there:

$$\text{II}b \quad t = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}\left(t'+\frac{vx'}{c^2}\right) = \frac{1}{\frac{1}{2}}\cdot\frac{1}{2}\cdot\frac{v^2}{c^2} = \frac{v^2}{c^2};$$

$$\text{for } \sqrt{1-\frac{v^2}{c^2}} = \frac{1}{2},\ \frac{v^2}{c^2}=\frac{3}{4};\ t = \frac{3}{4}$$

That is, according to the standards of simultaneity of system S′ your clock did not show 12:00 when I left station A, but already 12:45; which means that while I was on the way, it went on only by one fourth hour, and thus twice slower than mine. The same with clock C at A($x = 0$): At this moment $t' = \frac{1}{2}$ that clock is located relative to S′ at $x' = -v.t' = -\frac{1}{2}v$; (As before from equation II*a* solved for x'.) Hence it shows "at this moment"

IIb $$t=\frac{1}{\sqrt{1-\frac{v^2}{c^2}}}\left(t'+\frac{vx'}{c^2}\right)=\frac{1}{\frac{1}{2}}\cdot\frac{1}{2}\cdot\left(1-\frac{v^2}{c^2}\right)=\frac{1}{4}$$

That is, at that moment which for system S′ is simultaneous with this present moment here clock C_0 at A shows only $t = \frac{1}{4}$ (12:15), such that it too has gone only by one fourth hour during my trip from A to B.

Thus though not disagreeing on the readings of the clocks right next to us we yet come to different conclusions as to the length of time-intervals between given events measured by our clocks *because our standards of simultaneity of distant events differ*; namely: your inference that the duration of my journey from A to B was one hour rests on the assumption that the two S-clocks at A and B are synchronous. According to the standards of system S′ however they are not; yours is ahead of C_0 by $\frac{v^2}{c^2} = \frac{3}{4}$ (hour) Hence, in applying my standards of simultaneity to your set of clocks I judge them to be twice slower than mine."

Says the representative of Common Sense: "Why is it that your observers have to use those abstruse formulae to find out what a clock shows at a certain moment? Why can't they just look at them and tell like any sensible person?"

Answers the relativist: "Each one can at every moment tell what a clock right next to him shows. But *if a clock is far away he cannot without making a correction for the time it took light to travel from the clock to his place*. Suppose you stand on the earth and another person on Mars, both with clocks in your hands. You can immediately tell what your clock shows when you look at it; so can the Martian with his. But how are you going to determine which moment of your time corresponds to which of his? Even if you could see the Mars clock through an immense telescope you would in addition have to know how long it took the light wave which transmits the visual impression to travel from Mars to you; e. g. you would figure: That Mars clock did not stand on 1:00 the moment I saw it in that position, but at some earlier moment which I can find by dividing the distance between Mars and earth by the velocity of light and discounting this transmission time from the moment where I saw it in that position."

This method has been known and practiced for centuries by astronomers. *The new feature which the theory of relativity added to it was the discovery that it leads to results of only relative validity,* relative namely to the system in which the time determination is made. A system moving relatively to it finds by the same method a different time coordination of distant events; and the reason for this lies in the fact that a light ray travels with the same velocity c relative to all systems, no matter whether at rest or in motion with regard to one another. The Lorentz transformation is only the mathematical formulation for this invariancy of the velocity of light for two systems in relative motion.

Thus we realize: two observers passing each other disagree only on the question which moment of time (position of the clock hands) of a *distant* clock is simultaneous with a certain position of a clock *right next to them*, while on the latter they are perfectly agreed.

It might be objected here that "distant" and "nearby" are terms of only relative meaning; that what is "right next to me" in my estimation would be an astronomic distance for a submicroscopic being of atomic dimensions.[8] However these expressions have for us a very definite meaning: "next to us" or also "in our immediate neighborhood" we call an event which is near enough so that the transmission time of light from it is negligible *for the accuracy needed or obtainable in the particular time measurement;* or also, where we can identify the moment of *seeing* the event with that of its occurrence. "Far away" or "distant," on the contrary, we call an event from which the transmission time of light has to be accounted for, that is, is greater than the error of observation. E. g. if we read a clock only exact to 1 sec. a distance of about 150,000 km. would still be counted as in our immediate neighborhood. If however we could make a time measurement exact within 10^{-7}sec. then an event happening at a distance of only 300 m would already be called distant because, to determine the moment of its occurrence we would have to discount the time of light transmission, 10^{-6} sec, from the moment where we received the visual impression. The nature and dimensions of our organism and the accuracy of our physical apparatus determine in every case a certain range of errors of observation, and this range in its turn imparts a definite meaning to the terms "near by" and "distant." [E. g.

[8]On this point see the objection raised by Henri Bergson against the relativity of time, Durée et Simultanéité, Paris 1923, p. 73.

an astronomer in his most minutely accurate measurements would not attempt to correct his readings of the clock in the observatory for the transmission time of light across the room (of the order 10^{-8} sec.) whereas he would make the correction (of the order of several minutes) to determine the position of a planet at a certain moment.]

Observers then in relative motion disagree on the position of the clock hands of a distant clock not because they receive different visual impressions from it, but because they account differently for the time of light transmission.[9]

The misunderstanding of this point seems to have arisen because this one fact is not kept in mind: the time of a *distant* event is never—in classical mechanics as little as in relativity mechanics—directly observed or experienced; but it is determined only by a combination of measuring (which involves perception) and *computation*. In the terminology of the theory of relativity, it is true, the computation is frequently disguised as a "nothing but observation," due namely to the underlying scheme of imagining observers at every place "right next to a clock" synchronized with all others by means of a light-signal. That way the computation is simply performed in advance and once for all by all the observers who at places x set their clocks on $t = \frac{x}{c}$ on receiving the signal sent from $x=0$ at $t=0$. According to our theory it is only this computation, this dating back into the past of an event observed in the present, which contains the relative element, not the sense perception and thus we have come to see that the theory of relativity in no way implies the doctrine of solipsism.

[9]The fact that it is only on the coordination of *distant* events where two observers in relative motion disagree has been pointed out in the relativist literature; H. Thirring, in a controversy with E. Gehrcke (Naturwissenschaften, 1921) used it as an argument against the advocates of the solipsist implications of the theory of relativity. However, this author demonstrates his point only by means of a certain geometrical interpretation of the Lorentz transformation without laying open the root of the error: the different results in computing the transmission time of light for relatively moving observers.

IRIDIUM HARDEST METAL.

Iridium, a metallic element in the same chemical group as platinum, and often used as the tip for fountain pens, is the hardest pure metal, according to tests recently made by A. Mallock, and announced in the scientific magazine *Nature*. Molybdenum is the next hardest, with tungstein third. Nickel is the hardest of the common metals as it ranks fifth, the rare metal rhodium coming in fourth. These refer only to pure metallic elements, for some alloys, such as steel with a high percentage of carbon, rank higher than any.—*Science News-Letter*.

AIM AND CONTENT OF CHEMISTRY LABORATORY MANUALS.

By Clarence M. Pruitt,

Teachers College, Columbia University, New York.

The following report is a resume of an investigation to determine in some measure the correlation between the aims of Chemistry teaching as formulated by the committee on reorganization of science in the secondary schools, and the experiments given in fifteen representative Chemistry laboratory manuals. The writer recognizes the fact that such an analysis is arbitrary and there are perhaps many who would disagree both as to his method and his conclusions. There are indeed many difficulties in correlating the aim and the content of Chemistry laboratory courses. In the first place, the aims of the Chemistry course have not been definitely agreed upon by those chiefly concerned. Doubtless complete agreement is impossible of accomplishment. However, the aims agreed upon by many leading science teachers have been set forth in Bureau of Education Bulletin Number 26, 1920, which is entitled "Reorganization of Science in Secondary Schools." These aims are more representative than any Chemistry aims thus far formulated, and for that reason were used as a basis for this investigation.

The five aims of teaching high school Chemistry as formulated are:

1. To give an understanding of the significance and importance of Chemistry in our national life. The services of Chemistry to industry, to medicine, to home life, to agriculture, and to the welfare of the nation, should be understood in an elementary way.

2. To develop those specific interests, habits, and abilities to which all science should contribute. The powers of observation, discrimination, interpretation, and deduction are constantly called for in Chemistry and are so used in this subject as to require a high type of abstract thinking.

3. To build upon the earlier science courses, and knit together previous science work by supplying knowledge fundamental to all sciences.

4. To give information of definite service to home and daily life. This should be so interpreted as to include all topics which make for a better understanding of, and a keener insight into, the conditions, institutions, and demands of modern life.

5. To help pupils to discover whether they have aptitude for further work in pure or applied science, and to induce pupils having such aptitude to enter the university or technical schools, there to continue their science courses.

An analysis of the content of fifteen representative Chemistry manuals was made to see if present Chemistry manuals used in a large percentage of the high schools of the United States show any correlation with the above enumerated aims, and if so, to what extent. It is true that the exceptional teacher might so use any laboratory manual and *might* accomplish the aims listed above, through the use of the content of the manual. Laboratory manuals, no matter how complete, how perfect in content, will not be sufficient for the accomplishment of desired results unless properly supplemented and interpreted by the instructor. The pupil, his needs, purposes, and desires, together with the type of community and laboratory equipment, are a few factors in determining whether a given manual can correlate its content with the aims of instruction in Chemistry.

The first and third aim are less closely related to the laboratory work than the others formulated. The second, fourth, and fifth aim are closely related to laboratory work. This seems to support the idea that the Chemistry course should be built around the laboratory work. The laboratory should be a place for thinking, with a maximum of observation and a minimum of note-book writing. In much of the laboratory work it seems necessary for students to discriminate, compare, and generalize. There has been an over-emphasis on the acquisition of facts, as such, and on the making of ideal note-books, although each has its place.

In order to facilitate the analysis of the content of the various laboratory manuals, the experiments were classified under seven different groups, many of them admittedly overlapping. The grouping was as follows: (1) Preparation of Gases, (2) Preparation of Solids, (3) Neutralization, (4) Analysis (Qualitative and Quantitative), (5) Mechanical Manipulations, (6) Organic Chemistry, (7) Properties. The reasons for selecting the seven groups were largely arbitrary. Practically all the experiments were read. The writer has used three of the manuals in actual work for at least one year. It was often difficult to definitely classify an experiment. In addition to the classification in one of the seven groups, each experiment was classified as "practical"

TABLE I.

Manual No.	Date	No. Preparation Gases	%	No. Preparation Solids	%	No. Neutralization	%	No. Qualitative	%	No. Analysis Quantitative	%	Total % Analysis	No. Mechanical Manipulations	%	No. Organic Chemistry	%	No. Properties	%	No. Practical	%	No. Theoretical	%	No. Experiments
1	1907	13	26.16	9	18.4	1	2	5	10.2	3	6.1	16.3	0	0	4	8.2	16	33.8	0	0	49	100	49
2	1912	6	11.5	3	5.7	2	3.8	1	1.9	30	57.7	59.6	0	0	28	53.8	30	57.7	31	59.6	21	30.4	52
3	1912	0	0	0	0	0	0	12	50	12	50	100	0	0	0	0	0	0	24	100	0	0	24
4	1915	11	14.7	9	12	1	1.3	5	6.7	12	16	22.7	0	0	15	20	25	33.3	15	20	60	80	75
5	1915	15	14.9	20	19.8	3	3	8	7.9	14	13.9	21.8	3	3	19	18.8	41	40.6	14	13.9	87	86.1	101
6	1916	7	12.7	2	3.5	1	1.8	11	20	35	63.5	83.5	0	0	27	49.1	15	27.3	30	54.3	25	45.7	55
7	1917	19	22.6	12	14.3	4	4.7	5	6	15	17.9	23.9	1	1.2	10	11.9	25	20.8	9	10.7	75	89.3	84
8	1919	17	17	12	12	2	2	9	9	33	33	42	0	0	34	34	34	34	34	34	66	66	100
9	1920	20	25	10	12.5	2	2.5	15	18.9	19	11.2	30.1	1	1.2	9	11.2	25	31.2	12	15	68	85	80
10	1921	14	30.4	6	13	3	6.5	2	4.4	10	21.7	25.1	0	0	3	6.5	25	54.4	11	23.9	35	76.1	46
11	1921	12	20	6	10	3	5	4	6.6	20	33.3	39.9	3	5	31	51.6	26	43.3	32	53.3	28	46.7	60
12	1922	14	20.6	12	17.5	6	8.8	4	5.9	15	22.1	28	1	1.5	10	14.7	15	22.1	5	7.3	63	92.7	68
13	1924	16	22.2	10	13.9	5	6.9	7	9.7	11	15.3	25	4	5.5	13	18.1	27	37.5	6	8.3	66	91.7	72
14	1924	14	23.3	7	11.7	3	5	6	10	11	18.3	28.3	2	3.3	4	6.7	24	40	9	15	51	85	60
15	1924	13	15.5	12	14.3	4	4.7	2	2.4	10	11.9	14.3	3	3.6	13	15.5	31	37	29	34.5	55	65.5	84
		191	18.9	130	12.9	40	3.9	96	9.5	240	23.7	33.2	18	.18	220	21.8	359	35.5	261	25.8	749	74.2	1010

or "theoretical." Thus an experiment was always placed in two groups. For example: the experiment "Oxygen" was classified under "Preparation of Gases" and "Theoretical." In making this classification, if any errors occur they favor the "practical." A classification of exercises as "theoretical" or "practical" is, of course, subject to many errors, but in general it may be said that an experiment was classified as "theoretical" if its purpose was to illustrate a certain law or theory, or verify a certain set of facts. It was classified as "practical" if its purpose was to give the student information that might be of definite value in home and daily life, although perhaps not directly used by the student again. The tabulation sheet shows the results of the analysis, the number of experiments found in the various classifications, and the percentages which they are of all the experiments in the manual. A summary is given at the bottom of the table.

The table shows that there is a wide variation in the content of the manuals.

In some manuals much emphasis is placed on "analysis" and in other manuals this phase is practically ignored. This is also true of the other classifications tabulated. There seems to be a more or less equal distribution between properties, preparations, analysis and organic chemistry when experiments are considered as a whole, with wide variations within the individual manuals. Some of the manuals were admittedly for girls, while some seem best adapted to the needs of boys. However, there seems to be entirely too much emphasis laid on theoretical chemistry which really means that modern chemistry laboratory manuals have the college preparatory idea and that they do not serve as general basic training for the social needs of many boys and girls who will never enter college.

A final analysis was then made in determining the correlation between aim and content. Although the above mentioned table was given major consideration in this determination, the manual was also judged as a whole. When a correlation between an aim and the content of a given manual was low, it was given one point in the rating. If a high degree of correlation was found, the manual was given four points. Thus a manual might receive one, two three or four points.

In the summary it was possible for each aim to receive a maximum of sixty points, and for each manual to receive twenty points.

TABLE II.

Aim	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Summary
1	1	2	2	2	2	2	2	1	2	2	1	1	2	1	2	25
2	1	3	3	1	1	1	3	1	3	3	3	3	3	3	3	35
3	1	1	1	2	2	1	2	1	1	1	2	1	1	2	2	21
4	1	2	4	4	1	4	2	2	2	3	3	1	1	3	3	36
5	3	3	2	4	4	2	4	4	4	4	4	4	4	4	4	54
	7	11	12	13	10	10	13	9	12	13	13	10	11	13	14	

Explanation:

Poor....................1 Satisfactory....................3

Fair....................2 Good....................4

The table, which is self-explanatory, shows that the correlation between aim one and content is very low, but as pointed out in the beginning, the fulfillment of this aim, together with aim three, should largely be left to the Chemistry recitation. There seems to be a fair correlation between aim two and content, but little correlation between aim three and content. The fourth aim shows about the same correlation as the second aim, while there seems to be quite a high degree of correlation between aim five and the content of Chemistry laboratory manuals. This seems to verify the conclusion that too much Chemistry laboratory in high school has college preparation as the end in view. It is worth noting that the Chemistry manuals edited since the formulation of these aims show a somewhat higher degree of correlation. This is of some significance. The final conclusion is, that, taken as a whole, there is a relatively low degree of correlation between aim of Chemistry teaching and content of laboratory manuals, but in newer manuals, there seems to be an increasing tendency to correlate content with the aims formulated by the reorganization of science committee.

EXTENSION STUDY IN INDIANA TEACHERS' INSTITUTES.

More than 6,000 teachers in Indiana were enrolled last session in extension classes conducted by standard colleges and normal schools of the State in connection with teachers' institutes, which are required by law. Courses are chosen with a view to meeting the professional needs of teachers, and textbooks are selected by the board of the reading circle of the State Teachers' Association, of which the State superintendent is ex officio a member. Ten subjects were offered for study during the session 1925-26, and in all 235 classes were conducted, with a total enrollment of 6,184. Present interest in ethics and religion was shown by an enrollment of 3,616, more than half of all enrolled, for the study of Baily and Kent's "History of the Hebrew Commonwealth," which had been a textbook also the preceding year. For 1926-27 Moulton's "Modern Reader's Bible" has been selected for study in that field.

WHAT, IF ANYTHING, HAS REALLY BEEN PROVED AS TO THE RELATIVE EFFECTIVENESS OF DEMONSTRATION AND LABORATORY METHODS IN SCIENCE?[1]

By F. A. Riedel,
Supervisor of Science, Oread Training School,
University of Kansas.

There is a rumor abroad in the land that the laboratory and demonstration methods in teaching science are practically equal in teaching effectiveness, or that if anything the second method is superior in some respects. It will be noted that these assertions are based on research, and not opinion. And it is further to be noted that some of the less scientific statements regarding the issue are not made by the original researchers.

With a view to clarifying the situation the writer examined all the learning studies in the natural sciences published up to the winter of 1926. Of these only seven bear directly on the comparison of the two teaching methods, and over two dozen others bear on more or less closely related matters in science teaching. This of course does not include what are termed curricular studies. In a recent text by F. D. Curtis[2], there are summarized and discussed 26 studies, by 20 different students, writing for theses, dissertations or in personal studies. Besides this there have been added 8 other studies, the most complete in many respects being that of W. D. Carpenter[3]. The latter figure also includes an incomplete and unpublished study of the writer.

In the space available there will be presented in this and subsequent issues the outstanding facts that have been carefully gleaned by studies of the printed researches, and in a number of cases, the original data as may be obtained from the libraries where they are on file.

The criticism of these researches was made originally with one main purpose, that of finding out what had been done up to date, with a view to extending the research and getting both the positive and negative suggestions therein contained. In this way the comparison was made with as much openmindedness as possible and in the light of the newer conceptions of educational measurement and statistical treatment. At the

[1]Abstract of an 80 page report of work done in cooperation with the Lincoln School, New York City, while research assistant at that school.
[2]Investigations in the Teaching of Science, 1926, Blakiston's Sons and Co., Philadelphia.
[3]See *Journal of Chemical Education*, July, 1926.

same time the writer was visiting a half dozen high schools in New York City where with a previous background of 17 years' experience, he could observe classroom and laboratory practice and question both teacher and student as to the outcome of instruction. While such findings are admittedly subjective, they served to throw light on the problem in hand.

Now it is one thing to say that one or the other of the above methods of teaching is superior,—if in fact that were a safe assertion in view of the limited number of studies, admittedly small populations in most cases, inadequate statistical treatment in all cases except one and the general lack of reporting of details so that the results are verifiable. It takes a lot of assurance and an utter disregard for the cautious laborious and oft-repeated observations such as those in physical science or even biometry to give science teachers the impression that anything at all has been proved on such meagre evidence. And this is said with all deference to those science research students who have had the courage and wisdom to venture into this most worthy pioneer work.

It would be another thing to begin by defining just what is meant by the demonstration; what kind of demonstration; what is laboratory work, what kind, what antecedents, what time of year relative to student experience, what length of period, how about the setting up and putting away of apparatus, what previous science experiences, projects, etc.

In regard to the reported researches there are no doubt certain traditional methods of instruction assumed in the cases not specifically defined or described. Otherwise it may safely be asserted that there are as many variables in a given method as there are teachers, schools, localities, equipments, teaching experience, and repetitions.

In the next place there is a grave risk in assuming certain things concerning the tests, the testing and the statistical treatment. As to the tests, those reported cannot be said to represent much more than information, with more or less of comprehension of fact, and in a few cases with a limited ability to apply knowledge to new situations, and these on paper rather than in living or at least concrete representative situations. As to the testing, it is not certain that the methods were standardized altho authors in the larger number of cases thought, or seemed to show by samples of the test that they were objective. In no case was a long comprehensive test

program worked out that would insure even so much as tenta tive conclusions regarding the relative gain in skill, interest, ability to recognize real materials, confidence in working with real materials, confidence in the facts presumably learned, scientific attitude and increased spontaneous activity with similar science materials. In regard to the statistical treatment it is very questionable to put confidence in the equation of groups on the basis of intelligence alone; in pairing a boy with a girl, if done; in basing conclusions on small populations that are not necessarily representative or at least without regard to weighting; the use of per cent averages with no regard to the distribution within the group, and with no check on the significance of the stated differences. When it is also remembered that the tests may not be reliable, or the reliability not known, and that the tests are of insufficient range so that some students receive zero scores while others receive 100% scores the averages lose much of their significance. The writer seriously questions the statistical principle of general averages on even the large numbers except as follows: If in spite of all the disturbing variables of teacher personality, student personnel, kind of experiment, length of time, and all the rest, the general average discloses a difference that is significantly higher for one method than for the other, we would have a right to maintan that there was more or less scientific basis for statement of relative effectiveness. But in the process of averaging there may be lost sight of that which might well be most significant, namely, that certain experiments are best performed by one method; certain teachers succeed best in some or all experiments by one method; certain intelligence levels succeed better by one and some by another method in all or in certain experiments. We will never come out of the dark, and our educational science research will not gain the respect it could earn except by this more discriminating method of approach. Not all of the reported studies show caution and discrimination on the above items.

Let us interrupt the discussion at this point to review in a fashion not heretofore followed, the seven studies that are here alluded to. They are, in chronological order:

Wiley, W. H., 1918, "An Experimental Study of Methods Used in Teaching High School Chemistry."

Cunningham, H. A., 1920, "Under What Conditions in High School Science is Individual Laboratory Work Preferable and When do Lecture-Demonstrations Give Better Results."

Cooprider, J. L., 1922, "Oral versus Written Instruction, and Demonstration versus Individual (Laboratory) Work in High School Science."
Kiebler and Woody, 1923, "The Individual Laboratory versus Demonstration Method of Teaching Physics."
Anibal, Fred G., 1923-4, "Comparative Effectiveness of the Lecture-Demonstration and Individual Laboratory Method."
Carpenter, W. D., 1925, "A Study of the Comparison of Different Methods of Laboratory Practice on the Basis of Results Obtained on Tests of Certain Classes of High School Chemistry."
Colton, H. S., 1925, "Information versus Training: An Experiment in Laboratory Methods." Note: This last is on the college level and is not as directly related to the issue. The research of the present writer is omitted as is explained in another place.

The following remarks apply to the above studies which are as far as the writer can ascertain the only reported researches on the issue available up to the beginning of this year. While certain commentators refer to more than six such studies the ones specified by them are not of the character of scientific attempts so much as of good opinion. Or they are not actually relevant to the problem as stated. Unless otherwise noted the statements below refer to the six major high school studies.

Brief Summary of Outstanding Facts.

1. High School sciences represented: General Science 1, Biology 1, Physics 1, Chemistry 3; College Premedical Biology 1.

2. Science experiments or "exercises" in the foregoing: General Science 13, Biology 12 and 24, Physics (heat only) 14, Chemistry 3, 10, 25 and 10.

3. Cases in which the number of students used exceeded 20 (an arbitrary low minimum), 2.

4. Cases in which the author reports or shows the use of objective tests, of at least ten questions, 4.

5. Cases in which the tests were comprehensive and varied so as ostensibly to test other than information (but not including the additional "intangibles," so-called previously referred to), 3. (One of these was in the college study as between laboratory methods.)

6. Cases in which the researcher repeated using identical contents and methods, or attempted so to do, 3.

7. Cases in which the identical method was tested by other teachers or in other schools—*None.*

8. Cases in which modern statistical precautions and computations are used to safeguard the validity, reliability, and significance of the differences used, 1. (Also attempted in the college study with reference to the last-named item.)

9. Cases in which the research was published fully enough so

that (a). It could be intelligently criticized in all essential points, and (b). It could be repeated with a high degree of likeness by other persons who might wish to verify the results or test their general applicability or definitely modify the demonstration or laboratory method or content for further study—*None.*

The above comments should be held in mind while the reader recalls to memory any scientific study in, say, experimental psychology, of even as far back as that on "Memory" by Ebbinghaus, or an experiment in Mendelian factors by Morgan, not to mention experiments in physics or chemistry such as might be carried on by a Millikan or a Cady to see how utterly preliminary and how merely exploratory such researches as the above are to be considered. And again this is said with all deference to the educational pioneers. They deserve our profound respect for their initiatory measurements in a matter that lies very close to the hearts of all who have the progressive improvement of science teaching at heart.

These are some of the further considerations which may be well kept before us in judging the researches already made or those later to be announced.

I. ARE THE SCIENCE EXERCISES USED REPRESENTATIVE?
- a. Of the average practice of today in the East? West? U. S.?
- b. Of the average, large, medium, small, public, private, city or rural high school?
- c. Of the subject matter within the science?
- d. Of the reaction of students in so far as the novelty of science or of its particular treatment is responsible? (At the beginning of the year or in the first few months, students inexperienced in laboratory procedure might react unfavorably to that method, but later reverse their reaction.)
- e. Of average ability of the teacher with either or both methods?
- f. Of equipment whereby each method can operate at optimum efficiency?

II. ARE THE EXERCISES PRESENTED BY TRADITIONAL OR BY IMPROVED METHODS?
- a. Is large, striking or "real" (practical, or "life-like") apparatus used in either or both methods?
- b. Was handling of the apparatus, before, during or after the exercise permitted?
- c. Were the students gathered up close in case of demonstrations?
- d. Did the exercise introduce new studies, new concepts, or does it verify text or teacher statements, or does it involve problems real to the child, or does it vary according to the individual, in its content? Is discovery a dominant element?
- e. To what extent are the ideas discussed or diagrammed in the text or manual so as to furnish ready made ideas?
- f. Do tests insure not only the testing of ready made information, or verbal and visual memory or are new situations presented for solution? Are these verbal, recognitional, completion, concrete-objective, skill or otherwise?

It remains to be shown to what extent the visibility, size,

lifelikeness, appreciable importance or practicality, interest of one or the other sex in the materials, teacher personality, etc., affect the results. All such items should be reported in so far as practicable. Various researchers have called attention to some of these and other factors but rarely ever definitely or consistently enough for our purposes.

The time factor is likely to be very important. It is not always stated whether the period was 40, 50, 60 or 100 or 120 minutes long, and whether in this time the students were required to set up and take down the apparatus.

A few of the studies very well point out the need for very carefully controlled conditions, such as to the asking and answering of questions, the use of identical content and language by the instructor, and certain other matters of scientific control. However one of the studies which in the writer's opinion would otherwise have been valuable made no effort to secure homogeneous or equated grouping, nor is there any reported evidence of scientific control of time, apparatus, distance; or manner (specific) of presentation of the exercise. A study so conducted gives more negative than positive information to the classroom teacher. At best it indicates, in so far as it represents our national practice, that there is no outstanding difference in the amount of information taught by the two methods under consideration. The same author admits very frankly the limitations of his conclusions and the probability that there are a number of types of learning under one of the methods that he did not and could not measure. This is the leading important admission in this whole controversy. It is suggested in several of the other studies but in recent months there has been a tendency for certain reviewers to minimize this most essential detail. *No research known to the writer has made an adequate measurement of other than the merely informational aspect of the teaching.* The fact is that a test by its form and wording alone does not carry certain conviction that it measures other than memory of written or spoken words except when an accurate record has been kept of the words, objects, experiences, questions and the like to which the child has been exposed throughout the period of the research experiment (insofar as this is feasible or controllable). One may safely take the risk of repetition in saying that the *comprehensive testing of all the valuable or at least potentially measureable effects of a method have yet to be made for any science.* And until researchers demand

of those responsible for publicity a really adequate reporting of their findings, and unless they themselves make a very complete statement, in all frankness, of all the leading variables in their experiments, regardless as to whether favorable or unfavorable to their standing, or of acceptance of their conclusions, the teaching public is not going to get excited as to any research in science teaching regardless of its external pretentiousness. The same standards of integrity, accuracy, completeness, statement of errors, limitation of conclusions, repetition of experiments and scrupulous mathematical treatment which are the rule in physical sciences should obtain in this though more difficult and more vitally important field. On some of these points one is persuaded that there is much room for improvement. If the studies are considered as only preliminary and roughly tentative these objections are of less, weight.

It is not the purpose of this article to destructively criticize the many valuable studies in the learning of science. Rather it asks that a halt be called on modifying teaching procedure until something has really been proved to the satisfaction of the great thinking teaching public. It will be in order to follow this article by others definitely useful to the teacher and researcher.

At this stage of the problem two things can be done, one semi-scientific and rather subjective, the other not more scientific than what has gone before but yet very valuable if done on a large scale. Namely, all teachers interested in the solution of this matter of demonstration versus laboratory effectiveness can begin at once *a very close and critical study of just what happens in given demonstrations and laboratory exercises,* and which succeed best with certain apparatus, students, types of subject matter, and so on. In doing this, more careful objective tests, more varied test content, the taking of daily memoranda in usable form and their summary at, say, three months intervals would help much. Then if state teachers' meetings, county, district, township or smaller group meetings are held for definite round-table discussions based on the real data, there should be a beginning of rather wholesale experimentation, crude though it be, to find out what are the probable tendencies. Such work can be organized by the competent leadership in the several groups and the whole program passed along for refinement by such workers and schools as may have

the training and equipment to reach something like tenable conclusions. Would it be puerile to suggest that the teachers have an opportunity at this time much like that of the radio amateurs in the days when the whole boy population assisted in the discovery and perfection of radio design. The second line of work is the finding, working up into teaching units by both methods, of "likely" experiments amenable to treatment by both methods; and along with this trying out different tests written, pictured, pantomimed, using actual materials, etc. Even if subjective, certain carefully noted reactions of the students might be included in a final statement of the experiment. Such studies should also be presented at science teachers' meetings and the best selected and offered for publication. While statistics carry terror to many, it requires no pronounced mathematical ability to master the few most necessary concepts and devices which if used would render the research of far greater value These would include proper distribution and graphic representations of scores, coefficients of reliability of the tests, and experimental coefficients or critical ratios.

The next article will give additional details of the separate studies and suggestions, many of them made by the researchers themselves as to the follow-up work that lies ahead.

CELLULOID RIDERS FOR SONOMETERS.

By D. C. Barrus,

Mount Hermon School, Mount Hermon, Mass.

The usual paper form of a rider used in experiments with vibrating strings is rather unsatisfactory. It generally requires a little time to mount them on the strings and then they can be used for one trial only when they must be mounted again. This results in an unnecessary waste of time.

The writer has found that riders made from celluloid are very satisfactory and are the means of saving a great deal of time. Also the student's attention is not detracted from the main teaching of the experiment as is often the case while the instructor is taking the time to mount the paper riders.

In making these riders select a thin piece of celluloid. Cut circles out of the piece about the size of the cross section of a pencil. In the center of each circle punch a hole two or three times as large as the wire for which it is intended. If a punch is not at hand, melt a hole through the celluloid with a hot platinum needle. With scissors or a razor blade cut a slit from the outer edge to the center of the circle. This will enable you to slip the rider on the wire.

Several such riders can be mounted upon each wire of the sonometer and kept with the apparatus from term to term. The writer has found them very satisfactory in demonstrating sympathetic vibration and nodes and loops in vibrating strings.

SUGGESTIONS ON THE EVALUATION OF TEACHING PROCEDURES IN HIGH SCHOOL PHYSICS.

By A. W. Hurd,

University of Minnesota.

The following data are suggestive of what a teacher may do in evaluating his procedures in carrying on the work with a class in high school physics, thus laying foundations for improved procedures.

Two major questions are considered here; the first one bearing on the matter of the value of combined study and recitation periods in the classroom, as opposed to study being carried on outside of the classroom, and the second, bearing on the matter of the value of individual project work as opposed to work as a group. These will be made clear as the discussion proceeds.

The data given on the first question were gathered in the teaching of courses in high school physics during the school years 1924-26 inclusive. The classes of 1925-6 were three in number, enrolling 83 pupils in the beginning. These classes were carried through the year by the writer, there being a few changes at the middle of the year caused by transfers. During the year, the classes met two periods per day, whereas formerly the classes in this subject had operated on a time schedule of two periods for two days and one period for three days. The class time, therefore, was changed from seven periods a week to ten periods a week. The difference was thus three extra class periods to be used as the teacher saw fit.

During the first semester, no outside lessons were assigned, all study work being taken care of in the class periods. On the average, one period a day for three days a week was used for study, the same amount of time for class discussion, recitation and demonstration, and the remaining time, two periods, two days a week for laboratory work.

The question naturally arises as to the quality of work done by these pupils as contrasted with that done by a similar group the previous year meeting only seven class periods a week. Does this class do poorer or better work? Is there a greater variability among the pupils due to brighter and duller pupils having the same amount of time in which to do their work? How do ratings in physics compare with mental ability ratings under this scheme as contrasted with the former scheme?

Table 1 gives tabular data for two classes under the two schemes, showing the individual pupils; their Mean I. Q.'s ob-

tained from arithmetically averaging the two I. Q.'s resulting from the administration of the Miller Mental Ability Test, Form A, and the Otis Self-Administering Test, Form A. (The I. Q.'s according to the former test have been recomputed to approximate Stanford-Binet I. Q.'s); and the added scores of seven objective tests covering a random sampling of the course in physics I.

TABLE I.

Class 1924-5 (7 periods)

Pupil	Mean I. Q.	Score	Pupil	Mean I. Q.	Score
1	109	84	45	98	79
2	100	74	46	98	59
3	109	99	49	119	102
5	107	70	53	120	88
6	118	94	55	98	51
7	107	67	56	106	83
8	112	62	58	96	70
11	108	67	60	103	64
12	104	84	64	130	124
13	95	78	65	95	51
14	107	66	66	99	85
15	103	57	70	108	68
17	96	74	71	102	68
21	110	86	72	99	67
22	90	68	74	107	73
23	117	80	75	120	106
24	99	70	76	106	52
25	111	74	77	104	78
26	122	90	79	119	126
27	115	89	80	111	88
32	110	91	82	117	93
33	107	60	83	115	97
34	127	108	84	118	116
35	109	74	86	96	70
36	108	64	87	103	53
38	123	103	88	106	100
39	122	92	89	98	54
41	93	55	90	100	73
44	105	66	91	111	62

Mean I. Q.	107.7
S. D.	9.1
Mean Score	78.40
S. D.	17.9
Lowest I. Q.	90
Highest I. Q.	130
Lowest Score	51
Highest Score	126
Between I. Q. and Physics I. $r = .72 \pm .04$	

Class 1925-6 (10 periods)

Pupil	Mean I. Q.	Score	Pupil	Mean I. Q.	Score
1	95	72	42	102	61
3	104	84	43	104	82
4	127	101	45	116	98
5	103	65	48	104	79
6	112	51	61	111	93
7	111	79	64	102	53
8	115	101	50	102	48
9	101	72	51	121	121
10	110	85	62	113	65
11	99	92	63	91	66
13	104	88	52	100	69
14	112	80	65	115	108
15	92	71	69	112	81
16	111	73	71	110	53
17	100	84	72	113	97
19	116	78	73	120	92
20	104	52	74	127	126
21	112	71	77	113	73
24	105	92	78	113	91
25	115	95	79	92	44
27	109	91	81	120	106
28	117	88	82	101	89
30	117	85	83	101	82
31	126	124	84	99	66
32	108	95	85	102	58
34	113	81	86	98	74
35	110	80	87	109	55
36	113	87	89	113	112
37	106	53	90	106	79
39	112	107	92	113	79
41	108	62			

Mean I. Q.	108.7
S. D.	8.1
Mean Score	80.97
S. D.	18.7
Lowest I. Q.	91
Highest I. Q.	127
Lowest Score	44
Highest Score	126
Between I. Q. and Physics I. $r = .66 \pm .04$	

Possible score on Physics tests—148.

The classes are quite similar as regards the data shown. One fails to note any clear advantages or disadvantages of the ten period plan as compared with the seven period plan. From a practicable, everyday standpoint, if the tests be taken as a fair measure of values obtained from the course, the pupils may as well be allowed to prepare their own work outside of class periods. Lack of space here precludes a discussion of the tests, but they do cover the subject quite well and may be considered as better than the average. Certainly they are more valid than a teacher's

estimation of achievement would be. They include information and problem material.

The table speaks for itself. It is noted that the class as a whole is judged by the arithmetic means and standard deviations of its measures. These two functions will serve as rough characterizations. The two classes are seen to be almost on a par in both these respects.

For the class of 1924-5, the coefficient of correlation (Pearson) between physics' scores and I. Q.'s is $.72 \pm .04$. Similarly for the class of 1925-6, the coefficient is $.66 \pm .04$. Both are considerable, indicating that the mental tests measure something which is quite effective in producing success in the physics' tests.

It might be argued that with a given relationship between mental ability and ratings in physics, if the time element is made equal for all pupils, as was approximately done by the ten period a week plan, the coefficient would be increased. That is, if the relationship between physics and I. Q. is high with unequal times spent (the duller pupils would probably spend more time than the brighter in preparing outside lessons) with equal times, all working equally hard, the coefficient would be higher. This is not shown true in the data given. Some factors were evidently operating to decrease the coefficient.

One explanation would be the possibility that the pupils did not work equally hard while studying in the classroom. If this quality which is evidenced by intense application to work might be called industry, perhaps a consideration of this factor by the method of multiple correlation[1] might show a higher coefficient. Table II shows an attempt to do this. The ratings in industry are teachers' ratings, there being represented in each rating, four ratings of each student by different teachers, under whom the student had taken work.

The coefficient is increased slightly by this process. The lack of greater increase is probably due somewhat to the industry ratings being very inexact. Teachers do not know what industry is and probably make very bad guesses, mixing it in their minds with other things, possibly even mental ability itself, or success in their subjects, or pleasing personality, or the lack of obstreperousness, and the like. On the assumption that high mental ability combined with industry should produce the maximum achievement, this correlation should be much higher.

[1]Arthur S. Otis, Statistical Method in Educational Measurement. World Book Co., Chicago, 1925. p. 239.

The lack of better measures, or the presence of other factors are the probable explanations for the failure to show a higher correlation.

TABLE II.

(Multiple Correlation)

Pupil	Score Phys. I.	Industry	I. Q.
1	72	2.71	95
3	84	2.25	104
4	101	4.00	127
5	65	3.33	103
6	51	1.87	112
7	79	2.75	111
8	101	3.00	115
9	72	3.25	101
10	85	3.25	110
11	92	2.25	99
13	88	2.62	104
14	80	2.87	112
15	71	2.12	92
16	73	3.00	111
17	84	1.87	100
19	78	2.25	116
20	52	3.00	104
21	71	2.87	112
24	92	1.62	105
25	95	2.50	115
27	91	3.25	109
28	88	2.71	117
30	85	2.00	117
31	124	4.00	126
32	95	4.00	108
34	81	3.00	113
35	80	3.00	110
36	87	3.75	113
37	53	2.25	106
39	107	2.50	112
41	62	3.00	108
42	61	2.14	102
43	82	2.62	104
45	98	1.50	116
61	93	3.44	93
64	53	1.75	102
50	48	1.62	102
51	121	2.87	121
62	65	2.50	113
63	66	3.12	91
52	69	1.12	100
65	108	3.75	115
69	81	3.25	112
71	53	2.71	110
72	97	3.75	113
73	92	3.75	120
74	126	3.00	127
77	73	2.62	113
78	91	2.75	113
79	44	2.14	92
81	106	3.87	120
82	89	1.37	101
83	82	2.62	101
84	66	2.00	99
85	58	2.57	102
87	55	2.62	109
89	112	2.50	113
90	79	2.62	106
92	79	2.37	113

Physics I and Industry (rc_1)* $r = .42 \pm .07$†
Physics I and I. Q. (Mean) Miller and Otis (rc_2) $r = .66 \pm .04$
Industry and I. Q. (r_{12}) $r = .34 \pm .07$

$Rc_{12} = .69$

Toward the end of the first semester, a comprehensive test in "heat" was given to the pupils to discover their knowledge and abilities in problem solving, preliminary to the study of the subject to be carried on during the first six weeks of the second semester. During this six weeks, an individual-project plan was used. The pupils were allowed to plan their own work in the subject. In preparation for this, each pupil checked from a list of seventy-one everyday activities related to "heat," those activities he had engaged in or was engaging in, those he expected to

*Arthur S. Otis. Loc. cit.
†Otis Correlation Chart used.

engage in, and those he would like to learn more about. The assumption was that each pupil would plan his work as far as possible from the results of his study and checking of the list. The great variability of activities specified by the pupils makes it logical to conclude that if courses are to be adapted to the life needs of the pupils, no single six weeks' course would be best for every individual.

The point of view represented here is that individual instruction is not merely instruction on a fixed body of subject material, but the instruction of the pupil with his development in mind, he being permitted the liberty of choosing his own subject material as long as it concerns some phase of "heat." His training will consist then in character training, development of constructive ability, initiative, industry, and proper methods of work.

It may be well to add that the pupils' marks at the end of the course were not determined primarily by test ratings but by evidences of work, initiative, industry and constructive ability, in concrete form. This article is concerned with how well such a plan would result in achievement in the more or less usual understanding of the term, and does not attempt to outline a proper method of rating pupils on all phases of school work.

Tables III and IV present data showing the results of the testing on conventional subject material in 1925-6, and corresponding data on classes of 1922-3, 1923-4, and 1924-5, to be used in making comparisons. One feature was added during this course in 1925-6, namely, a minimum requirement list and test given to the pupils. No drill work in class was engaged in, however. Most of the time usually given to class recitation was used in topics given by pupils, demonstration experiments by the instructor and work on the projects by the pupils. All the usual laboratory experiments were performed by the instructor with the aid of certain pupils and the pupils were allowed to write up these experiments, or not, as they chose.

One can very readily see that if a pupil spent his time working on the topic "Health in heating, ventilating and humidifying the home," that his knowledge of this subject would be much more detailed than if he had tried to cover the whole subject of "Heat" as outlined in one of the standard texts, but that he would not probably have as varied a knowledge of the subject of heat in general. Some might object to the liberty given to concentrate on such a topic, but if the pupil by means of a short time

spent on a minimum requirement list, is able to get as high a rating on heat in general as one who has taken up the subject in the conventional manner, the objection will probably be withdrawn. Briefly this is the philosophy underlying the plan.

The tabulated data show that the class of 1925-6 is almost equal to the class of 1924-5 taught by the conventional text-book-recitation method in scores in "heat" though apparently slightly higher in mental ability ratings. The text-book-recitation class of 1923-4 is higher on heat scores, but is also a superior class mentally. The minimum requirement tests evidently

TABLE III.
DATA for CLASS in HEAT 1925-6
INDIVIDUAL PROJECT METHOD

Pupil	Prelim.	Final	Gain	I. Q.	Pupil	Prelim.	Final	Gain	I. Q.
2	30	52	22	115	43	35	91	56	104
3	39	84	45	104	45	31	94	63	116
4	37	95	58	127	46	34	50	16	98
5	24	40	16	103	48	36	56	20	104
6	31	67	36	112	64	26	64	38	102
7	34	79	45	111	75	37	89	52	112
12	30	40	10	102	50	43	55	12	102
13	24	77	53	104	51	38	99	61	121
14	24	52	28	112	62	23	52	29	113
15	38	67	29	92	63	28	61	33	91
16	48	76	28	111	52	31	32	1	100
17	22	74	52	100	54	32	85	53	118
18	50	63	13	116	55	52	80	28	106
19	40	73	33	104	65	38	114	76	115
20	16	71	55	104	67	33	66	33	103
23	50	79	29	115	69	24	79	55	112
24	28	93	65	105	71	26	66	40	110
25	63	93	30	115	72	15	78	63	113
27	43	88	45	109	73	34	93	59	120
28	41	86	45	117	74	36	113	77	127
30	33	63	30	117	77	33	81	48	113
31	34	103	69	126	78	32	103	71	113
32	36	111	75	108	79	29	40	11	92
34	46	81	35	113	81	45	80	35	120
35	40	68	28	110	82	56	103	47	101
36	48	83	35	113	83	42	90	48	101
37	18	65	47	106	87	16	53	37	109
39	55	96	41	112	88	32	91	59	113
40	11	59	48	106	89	39	82	43	113
41	27	55	28	108	90	22	81	59	106
42	30	56	26	102	92	55	83	28	113

Possible Score	137
Mean Preliminary Score	34.56
S. D. Preliminary Score	10.74
Mean Final Score	75.70
S. D. Final Score	18.8
Mean Gain	41.14
Norm (Median)	69.33
Mean I. Q.	109.86
S. D.	7.7

Correlation between Final Scores and I. Q. = .51 ± .06

TABLE IV.

Test Results—Classes of 1922-3, 1923-4 and 1924-5.

Class of 1924-5—58 pupils taught by text-book-recitation method.

Mean I. Q. (Miller and Otis)	107.67
S. D. I. Q.'s	9.0
Mean Score Heat	77.9
S. D. Heat	18.8

Class of 1923-4—35 pupils taught by individual-project method. (Section 1.)

Mean I. Q. (Miller and Otis)	112.7
S. D. I. Q.'s	7.3
Mean Score Heat	76.9
S. D. Heat	22.4

Class of 1923-4—35 pupils taught by text-book-recitation method. (Section 2.)

Mean I. Q. (Miller and Otis)	112.2
S. D. I. Q.'s	8.7
Mean Score Heat	84.07
S. D. Heat	20.7

Class of 1922-3[2]—39 pupils taught by topic method. (Section 1.)

Mean I. Q. (Terman)	106.2
S. D. I. Q.'s	8.8
Mean Score Heat	71.1
S. D. Heat	19.4

Class of 1922-3[2]—39 pupils taught by problem method. (Section 2.)

Mean I. Q. (Terman)	107.6
S. D. I. Q.'s	8.4
Mean Score Heat	72.3
S. D. Heat	19.9

were of some value to the class of 1925-6. The data for the other classes are interesting for comparisons.

The coefficient of correlation for the class of 1925-6, between test scores and I. Q.'s is considerably lower than those usually obtained with these tests as they have been used by the writer, which would be expected as pupils in this group were not working on the same materials most of the time.

From the data, it is reasonable to conclude that an individual-project method as conducted in 1925-6 is almost equal to the more conventional text-book-recitation plan in achievement on conventional test material. Might it reasonably be assumed that the training received in industry, initiative, self-reliance and constructive ability makes it a more desirable method on the whole? It's advantage in allowing pupils to work on problems connected with daily life applications is also worthy of consideration.

[2]Archer W. Hurd. A Topical Versus a Problem Method in High School Physics. Bulletin of The University of Minnesota, Volume XXVIII, No. 2, Jan. 17, 1925.

To establish 100 scholarships for rural teachers in summer schools of George Peabody College for Teachers, Nashville, Tenn., the sum of $100,000 has been donated to the college.

THE FOURTH PROPORTIONAL AND SIMILARITY IN CONSTRUCTION WORK.

By Elmer R. Bowker,

Public Latin School, Boston, Mass.

When the Greeks first proved the proposition that the sum of the three angles of a triangle equals two right angles, they did it for three particular cases: first, for the equilateral triangle by use of the regular hexagon; second, for any right triangle by use of the rectangle; and third, for any other triangle by dividing it up into two right triangles. They appeared to fear that a general proof might be vitiated if it were applied to a figure in any way special or peculiar. Herein lies one of the differences between Greek geometry and geometry as it is taught today. The Greeks shunned the idea of a general proof as inconclusive while we, on the other hand, demand a general proof of a proposition as the only conclusive one. We go further than that in refusing to honor a proof based on a special figure if the proof itself is made easier by use of the special properties of this figure.

The idea of generality of method has a distinct application in the psychology of teaching. We have learned that a general method which may receive concrete application to a variety of special cases is a necessary tool for the organization of any body of subject matter. In algebra we group manipulation work about a general principle for training and practice on the principle involved. Indeed, we are accustomed to assert that the entire subject matter of algebra is grouped about the central idea of functionality or of the equation. In geometry we group propositions about the central ideas of congruence, similarity, and parallelism. The search for the general method or the underlying principle is not a habit peculiar to the teacher alone. It is the universal habit of the learning mind. The inquiring pupil is constantly seeking for the underlying principle in any process. Algebra pupils become accustomed to the idea of a general method in manipulation and they are mystified when we can give them no general method which may act as an "open sesame" for all kinds of verbal problems.

Most of our text books in geometry lay down three general methods of attack for the solution of construction problems, the synthetic method, the analytic method, and the method of intersection of loci. The synthetic method is of little use in construction work. Very few problems can be solved by this

method and those that can be solved are so easy that they scarcely deserve the name of problem. Text book writers know this of course and it seems a reasonable guess to say that they include synthesis with the other two methods simply as a rhetorical gesture. The other two methods, on the other hand, are powerful tools whose use must be mastered if the pupil expects to be successful in construction work. This paper is not concerned with the use of these three methods but with the exposition of a fourth method based on the fourth proportional and the concept of similarity.

We meet the fourth proportional first in book three and here it may be used for the geometric solution of equations of the type $x = \frac{ab}{c}$, $x = \frac{b^2}{a}$ and $x = \frac{2ac}{b}$. Such an application is valuable in preparing for the work with areas in book four.

In the fourth book we find problems of the following general type:

On a given line as base, altitude or side construct a triangle, parallelogram, rectangle, equal in area to n times the area of a given triangle, parallelogram, rectangle.

Some concrete representations of this general problem are as follows:

(a) On a given line as base construct a triangle equal in area to a given triangle.

(b) On a given line as altitude construct a rectangle equal in area to three times a given parallelogram. The wide-awake teacher improvises many such problems based on the general statement above. All of them when properly analyzed reduce to the solution of an equation such as $x = \frac{3ab}{c}$ and this of course involves the use of the fourth proportional.

Another problem which is emphasized in book four is as follows:

To construct a square having a given ratio to a given square.

When the given ratio is expressed in abstract terms such as m to n the solution given in our text books is an intricate process which is easily forgotten and has little to commend it for use in concrete cases. For this reason we are accustomed to state the ratio in specific terms such as 2 to 5. If the problem is so stated we can by analysis and use of the fourth proportional reduce the

solution to a more rational basis. If we are given a square with side s and wish a square with side x whose area is 3-4 of the area of the given square, we write the equation

$$\frac{4}{3} = \frac{s^2}{x^2} \text{ whence } \frac{2}{\sqrt{3}} = \frac{s}{x}$$

Assume a line of unit length and determine lines equal to 2 units and $\sqrt{3}$ units. Find then the fourth proportional to 2, $\sqrt{3}$, and s which is the side of the required square.

If now we combine the concept of similarity with the idea of the fourth proportional we obtain a method which is certainly more useful than the synthetic method and for that reason more worthy of being elevated to the status of a general method. The concept of similarity may be stated in simple language as follows:

Given any plane figure, there exists anywhere a figure of the same shape and of any size we may desire.

Along with this concept must be developed the idea that corresponding points have the same relative positions and that corresponding lines are in the same ratio. The pupil must be made to realize that if he has given any figure and a single line of a required similar figure, he may obtain any other lines of the required figure by constructing fourth proportionals. He must form a "mind set" involving these concepts as he has for the methods of analysis and intersection of loci, a "mind set" which he recognizes as a general method of attack for a new problem.

The use of the method will be better understood by seeing how it works. It is not asserted that the method as used in these illustrative problems is the easiest method. There is in each case a special solution possible by analysis of the particular properties of each figure. But a special solution is generally harder to find. The advantage over these special solutions lies in the use of a general method which may be applied to various other problems.

1. Given the perimeter construct a triangle similar to a given triangle.

Given: the perimeter p and a triangle with sides x, y, and z.

Required: a triangle similar to the given triangle with sides a, b, and c whose sum equals p.

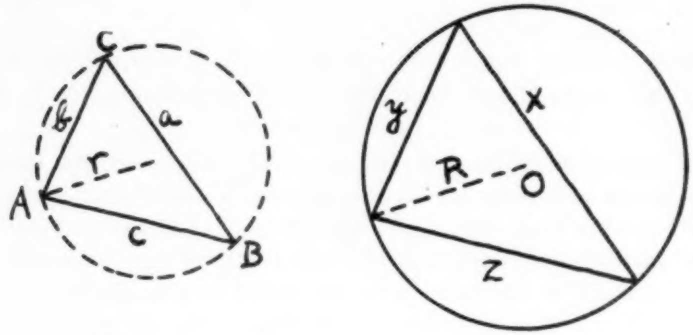
CONSTRUCTION.

Let s equal the perimeter of the given triangle.

Find a fourth proportional to s, p, and x thus obtaining a side a of the required triangle.

Obtain sides b and c by a similar construction.

2. To inscribe in a given circle a triangle similar to a given triangle.

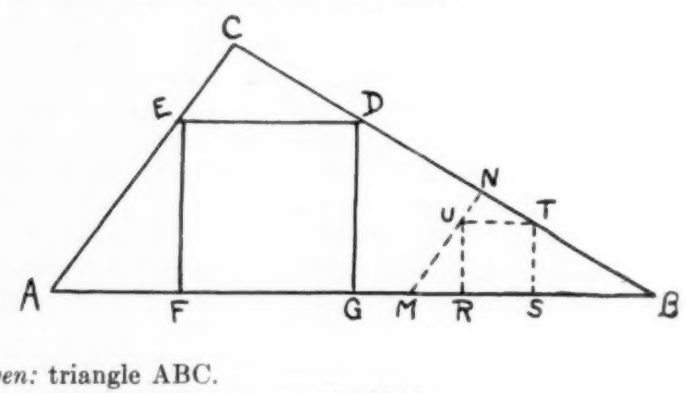


Given: triangle ABC and circle O.
Required: to inscribe in circle O a triangle similar to ABC.

CONSTRUCTION.

Circumscribe a circle about triangle ABC.
Find fourth proportional x to r, R, and a.
Find fourth proportional y to r, R, and b.
Construct triangle with sides x, y, and z.

3. To inscribe a square in a given triangle.



Given: triangle ABC.
Required: to inscribe a square in ABC.

CONSTRUCTION.

Draw any square RSTU with base in AB and vertex T in side BC.

Construct MN through vertex U parallel to AC.

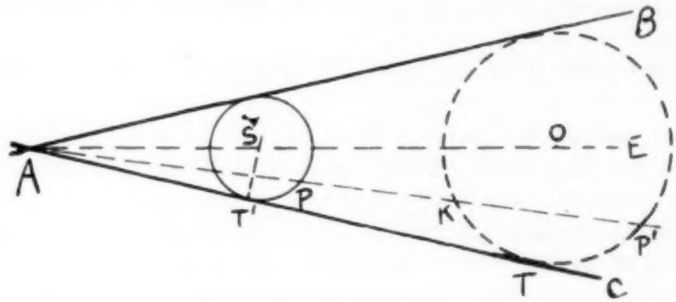
Find d the fourth proportional to MB, AB, and BT.

Lay off d on BC from B obtaining vertex D of the required square.

Construct the required square DEFG.

It is possible to shorten the solution of this problem by drawing BU and producing it until it cuts AC. This would determine the vertex E of the required square. Such a solution however does not bring out the idea of proportionality of the figures as well as the indicated solution.

4. To draw a circle tangent to two given intersecting lines and passing through a given point.



Given: point P and intersecting lines AB and AC.
Required: A circle passing through P and tangent to AB and AC.

CONSTRUCTION.

Construct AE the bisector of angle BAC.

Draw any circle O tangent to AB and AC.

Draw AP and produce until it cuts circle O at K and P′.

Construct t a fourth proportional to AP′, AP, and AT.

Lay off t from A on AC obtaining point T′ which is the point of tangency of the required circle with AC.

The perpendicular at T′ to AC intersects the bisector AE at S and the required circle may be drawn with center S and radius ST′.

Since AP cuts the circle O at another point K a second fourth proportional y may be found to AK, AP, and AT. This determines a second point of tangency and hence a second circle may be drawn.

These four problems are sufficient to indicate the range of application of the method. The following is a list of some inter-

esting problems which may be solved by this method. It is not exhaustive. The reader will discover other applications.

To circumscribe about a given circle a triangle similar to a given triangle.

To inscribe a square in a semi-circle.

To inscribe in a given circle a regular polygon similar to a given regular polygon.

To construct a regular pentagon, given one of the diagonals.

Given the altitude to construct a triangle similar to a given triangle.

To construct an equilateral triangle given the radius of the inscribed circle.

To construct a triangle given the perimeter and the three angles.

To construct a square, given the sum of the diagonal and one side.

This method has another value extraneous to its application to construction work. It serves to deepen the understanding of the concept of similarity. In our American geometry courses, we use the parallel postulate as a jumping off place for deduction instead of the concept of similarity. As a consequence similar figures do not receive the extended treatment which their importance warrants. Similarity should be developed informally along with the other fundamental notions in the pre-demonstration work. It is not in the majority of cases. It is usually put off until the formal treatment in book three and thus it appears to the pupils as an excrescence on the main stem of the logical development instead of an integral and parallel growth. To pupils who have heard nothing of similar figures until the third book and see it there in connection with triangles only the idea of the similarity of circles is sometimes startling. Any method then which will deepen and extend the idea of similarity appropriates to itself an intrinsic value.

In the report by the National Committee on Mathematical Requirements one chapter is devoted to a discussion of terms used in mathematical teaching. It is recommended that certain terms be dropped from the vocabulary since they name concepts or entities which have lost their importance in elementary mathematics. Among these we find the term "fourth proportional." It is difficult to see how constructions of the fourth book are to be handled unless we use the unique line which bears this name. We cannot abandon the use of this line. If it is simply the name

the Committee objects to and wishes to substitute another we have no complaint. It matters not whether the unique line in question be called a "fourth proportional" or a "jabberwock." The line and its relations must be retained.

"A rose by any other name would smell as sweet."

PROBLEM DEPARTMENT.

CONDUCTED BY C. N. MILLS,

Illinois State Normal University, Normal, Ill.

This department aims to provide problems of varying degrees of difficulty which will interest anyone engaged in the study of mathematics.

All readers are invited to propose problems and to solve problems here proposed. Drawings to illustrate the problems should be well done in India ink. Problems and solutions will be credited to their authors. Each solution or proposed problem, sent to the Editor, should have the author's name introducing the problem or solution *as on the following pages.*

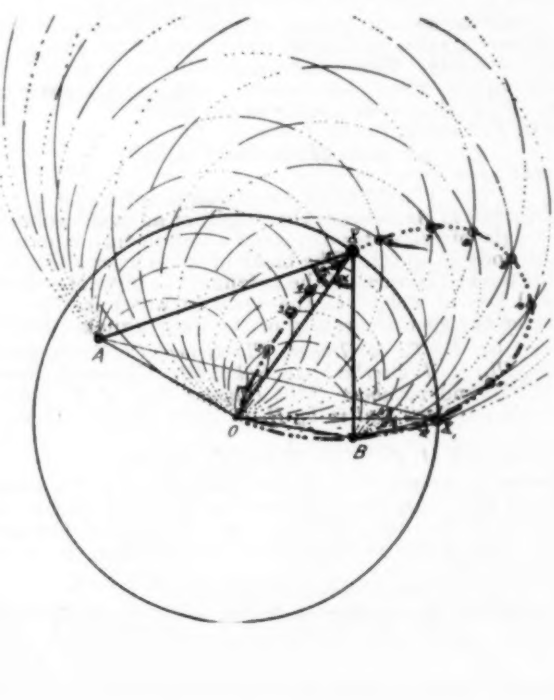
The Editor of the department desires to serve its readers by making it interesting and helpful to them. Address suggestions and problems to C. N. Mills, Illinois State Normal University, Normal, Ill.

SOLUTION OF PROBLEMS.

956. *Proposed by Victor A. Ivanhoff, Pittsburgh, Pa.*

On a round billiard table two balls have a given position. Find the point X, by geometric construction, on the circumference of the table where the first ball must strike in order to hit the second ball.

I. *Solved by the Proposer.*



On AO and OB draw the segments, containing the same angle. $\angle A1O = \angle B1O$, $\angle A2O = \angle B2O$, and so on. The curve which passes through the points O, 1, 2, 3, 4, 5, X, 6, 7, 8, 9, 10, 11, X_1, 12, B, intersects the circle at the required points X and X_1.

II. *Solved by Michael Goldberg, Washington, D. C.*

The points X (there are at least two of them) can not be located by Euclidean constructions. The problem is discussed in the "American Mathematical Monthly" of Oct., 1926, on pages 420-21, in the article on "The Complex Variable in the Solution of Problems in Elementary Analytic Geometry" by G. A. Bingley. It is shown that the points X are the intersections of a rectangular hyperbola with the circle.

Let the given points be $(a, 0)$ and (b, c) where the center of the circle is the origin. Then if (x, y) is one of the points X, the line joining it to the center bisects the angle between the lines joining it to the given points. The slopes of the latter two are $y/(x-a)$ and $(y-c)/(x-b)$, while the slope of the bisector is y/x. Using the relation $\tan(A-B) = (\tan A - \tan B)/(1+\tan A \tan B)$,

$$\frac{\dfrac{y}{x-a}-\dfrac{y}{x}}{1+\dfrac{y}{x(x-a)}} = \frac{\dfrac{y}{x}-\dfrac{y-c}{x-b}}{1+\dfrac{y(y-c)}{x(x-b)}}$$

which reduces to $\dfrac{ay}{r^2-ax} = \dfrac{cx-by}{r^2-bx-cy}$, where $r^2 = x^2+y^2 =$ constant.

Upon expanding, the equation of an ellipse is obtained

$$ac(x^2-y^2)-2abxy+r^2(a+b)y-r^2cx = 0.$$

The intersection of this ellipse with the circle $x^2+y^2 = r^2$ are the required points. This furnishes another explanation of the position of the points X, but their determination requires the solution of a quartic equation.

957. *Proposed by I. N. Warner, Platteville, Wis.*

I desire to find the specific gravity of a piece of wood that will not sink in water. Given a piece of copper which weighs 36 ounces in air and 31 ½ ounces in water. The wood weighs 70 ounces in air. The pieces of wood and copper, when tied together, will sink in water and weigh 11.7 ounces. Find the specific gravity of the wood.

Solved by C. F. Newton, South Byron, N. Y.

$$\text{Specific gravity} = \frac{\text{Weight of substance in air}}{\text{Weight of an equal volume of water}}.$$

By the *Principle of Archimedes* the weight of an equal volume of water equals the weight of the water displaced which in turn equals the loss of weight of the body in water. The block of wood loses all its own weight in air plus $(31.5-11.7)$ ounces of the weight of the piece of copper. Therefore the total loss of weight of the wood in water is $(70+31.5-11.7)$ ounces. Hence the specific gravity of the wood equals 70/89.8, or .779.

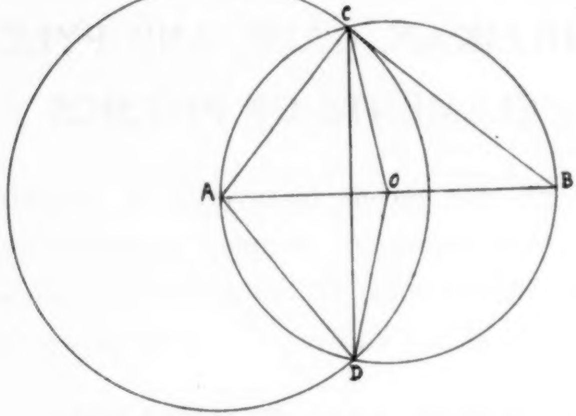
Also solved by *R. T. McGregor, Elk Grove, Calif.; Raymond Huck, Shawneetown, Ill.; C. J. Overbeck, La Salle, Ill.; Ulysses S. Brooks, Elizabeth City, N. C.;* and *members of the Physics class of the High School at Benton, Ill., the solutions sent in by H. G. Ayre; Michael Goldberg, Washington, D. C.*

958. *Proposed by A. J. Paterson, Wheeling, W. Va.*

The center of one circle lies on the circumference of a smaller circle. The crescent of the larger circle is equal to the total area of the smaller circle. Show that the angle K formed by the radii of the larger circle, drawn to the ends of the common chord, is such that, $K = 2\pi+\tan K$. Find $\angle K$ in degrees.

Solved by George Sergent, Tampico, Mexico.

Let the radius of the smaller circle, O, be unity; A the center of the



larger circle; AB = 2, a diameter of circle O, R the radius of circle A, and CD the common chord. The area of the smaller circle is π.

$\angle BAC = K/2$, and $\cos (K/2) = AC/2$.

$AC = R = 2\cos(K/2)$, and $BC = 2\sin(K/2)$.

The area of circle $A = \pi R^2 = 4\pi\cos^2(K/2)$.

The area common to the two circles is equal to sector COD plus sector CAD minus quadrilateral CADO. Sector COD $= \pi - K$, expressed in radians. Sector CAD $= 2\cos^2(K/2)\times K$. The quadrilateral CADO = right triangle ACB $= (1/2)(BC\times AC) = \sin K$. Setting up the expression for the equality of areas, and substituting $(1+\cos K)$ for $2\cos^2(K/2)$, we get

$$2\pi(1+\cos K)-[\pi-K+(1+\cos K)K-\sin K] = \pi.$$

Simplifying, $2\pi\cos K - K\cos K + \sin K = 0$.

Dividing by $\cos K$, we get $K = 2\pi + \tan K$.

Solving the expression by trial, $K = 102°\ 32'\ 48''$.

Also solved by Michael Goldberg, Washington, D. C.; and the *Proposer.*

959. *Proposed by I. N. Warner, Platteville, Wis.*

Two men were walking along a railway track, each at the rate of 3 miles per hour, and in opposite direction. A passing train ran completely by one of them in 5 seconds and by the other in 6 seconds. How many feet long was the train?

I. *Solved by E. de la Garza, Brownsville, Texas.*

Johnny's Method. Editor. See Paul Lygda's article in SCHOOL SCIENCE AND MATHEMATICS on the solution of Problems.

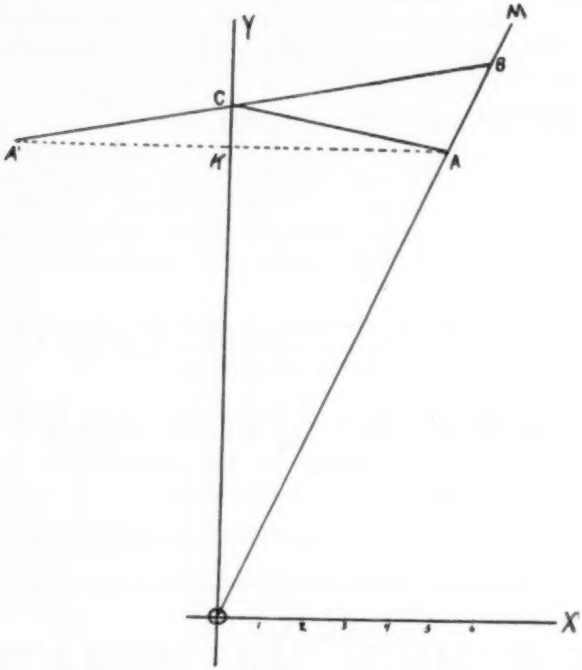
We can divide the problem in three different and important situations. First, when the race starts, the front of the train and the two men are together. We will suppose the train and one man going north, the other man going south. Second, five seconds later. The men are at 22 feet north and south of the starting point, and the rear of the train is at 22 feet south of the starting point. Third, one second later. The southbound man has quit, the northbound man has advanced from 22 feet north to 26.4 feet north of the starting point, and the rear of the train has moved from 22 feet south to 26.4 feet north of the starting point. Hence the rate of the train per second is 48.4 feet. The train moved 290.4 feet while the one man moved 26.4 feet. Hence the train has a length of 264 feet.

II. *Solved by P. H. Nygaard, Spokane, Wash.*

Let X equal the length of the train in feet. Since the men are walking 4.4 feet per second, the man going opposite to the direction of the train goes 22 feet while it is passing, and the other man goes 26.4 feet. While passing the first man, the train goes $(X-22)$ feet, and $(X+26.4)$ feet

for the other man. These distances are in the ratio of 5/6. Hence X = 264 feet.

III. *Graphic Solution by E. de la Garza.*



The X-axis is the time-axis; and the Y-axis is the distance or length-axis. Draw any line as OM. Note where this line cuts the ordinates for the times 5 seconds (A) and six seconds (B). Construct the symmetric of point A with respect to the Y-axis, which is A′. Join A′ and B; this line cuts the Y-axis at C. CK, on the Y-axis corresponds to the 5-seconds abscissa of the man going in opposite direction to the train. Hence CK = 22 feet. Then taking space CK as a basis graduate the Y-axis. The distance OC = 264 feet.

Also solved by *Wayne French, Battle Creek, Mich.; R. V. Maneval, Russell, Kansas; G. R. Ray, Spring Valley, Ill.; Marquess Wallace, Mexico, Mo.; C. J. Overbeck, La Salle, Ill.; Walter A. Schulze, Brownsville, Texas; F. A. Caldwell, St. Paul, Minn.; R. T. McGregor, Elk Grove, Calif.; Ulysses S. Brooks, Elizabeth City, N. C.; C. F. Newton, South Byron, N. Y.; Richard Holley, Stigler, Okla.; George Sergent, Tampico, Mexico; T. E. N. Eaton, Redlands, Calif.*, sent in the solutions of several members of the Algebra class.

960. *For High School Pupils. Proposed by the Editor.*

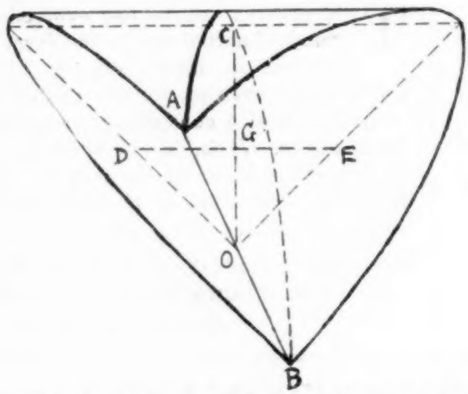
Two circular cylinders, of radius a, intersect each other at right angles, the axis of one intersecting the axis of the other. Show that the volume common to the cylinders is $\dfrac{16a^3}{3}$. This problem can be worked without the use of the calculus.

I. *Solved by the Editor.*

Divide the given solid into thin sections which are parallel to the plane of the axes of the cylinders. The central section has the shape of a square,

and its inscribed circle has a radius of a. The total of the inscribed circular sections make a square which is inscribed in the given solid. Let V equal the required volume. Then, $V : \frac{4}{3}\pi a^3 = 4a^2 : \pi a^2$. Hence $V = \frac{16}{3}a^3$.

II. *Solved by George Sergent, Tampico.*



The intersection of the two cylinders determines two ellipses having a common axis, AB = $2a$, perpendicular to the axes of the cylinders. The solid common to the two cylinders is formed by four equal cylinder trunks. Each of these trunks is bounded by a cylindrical lateral surface and by two half ellipses. The volume of the cylindrical trunk is equal to the product of the right section by the line drawn between the bases through the center of gravity of the right section, and parallel to the generatrix. Thus if OC, perpendicular bisector of AB, is the radius of the right section, G, on OC, the center of gravity of the right section, DE, the line through G, perpendicular to OC, and limited by the bases, we have

Volume of trunk = $\pi a^2/2 \times DE$.

OG = $4a/3\pi$. Since the triangle ODE is isosceles and right angled, we have GD = GE = OG. Then DE = $8a/3\pi$. The volume of the cylindrical trunk is

$$\frac{\pi a^2}{2} \times \frac{8a}{3\pi} = \frac{4a^3}{3}$$

The total required volume is $16a^3/3$.

PROBLEMS FOR SOLUTION.

971. *Proposed by John Ankebrandt, Gunnison, Colorado.*

Find the smallest number which when divided by 2 has a remainder of 1, when divided by 3 has a remainder of 2, when divided by 4 has a remainder of 3, and so on, but when divided by 17 there is no remainder.

972. *Proposed by Orville F. Barcus, Columbus, Ohio.*

Given an angle BAC with given side BA, and a given line BD intersecting side CA at the point E. Determine the point E so that AD:AE = BD:AB.

973. *Proposed by Raymond Huck, Shawneetown, Ill.*

Suggested by Problem 960. Determine the edge of the maximum cube inscriptible in the common volume of the two intersecting cylinders.

974. *Proposed by J. F. Howard, San Antonio, Texas.*

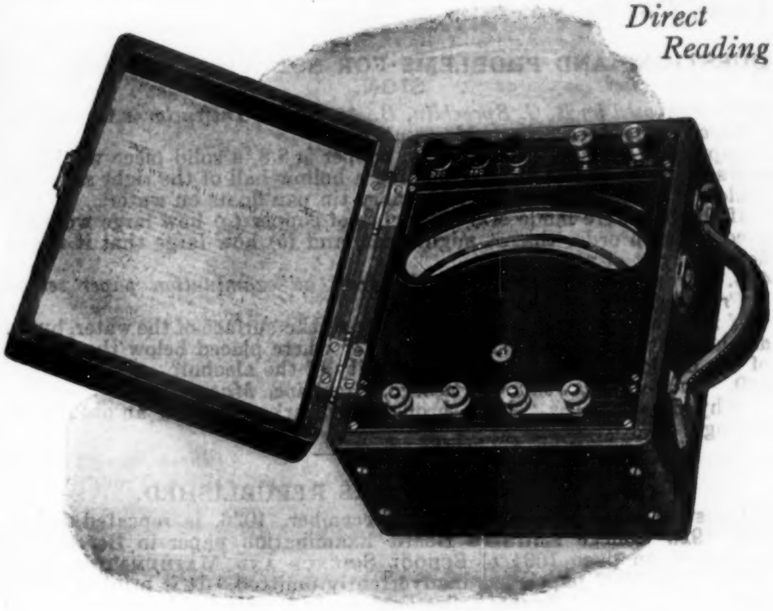
If the points L, M, N be taken on the sides BC, CA, AB of a triangle, the circumcircles of AMN, BLN, CLM meet in a common point.

975. *For High School Pupils. Proposed by I. N. Warner, Platteville, Wis.*

How many board feet of lumber in a stick 4″ by 4″ at one end, 2″ by 12″ at the other, and 16 feet long?

JEWELL

Pattern No. 8 Wattmeter Direct Reading



Low Scale Wattmeter

Practically every school laboratory has a need for the Jewell Pattern No. 8, low scale, direct reading wattmeter.

The low scale full range of five watts can be used in many ways to good advantage. It enables accurate readings down to one-tenth watt with a reading error not exceeding .01 watts.

Ranges of 0-5-10-25-50-100 watts with current coils wound for .25-.5 amperes and potential coils for 20-100-200 volts are available.

This wattmeter will be found exceedingly valuable in tests of low wattage circuits where it was possible previously to obtain wattage only by the Voltmeter, Ammeter method.

Write for catalog supplement No. 16-A which describes this instrument.

Jewell Electrical Instrument Co.

1650 Walnut St. - Chicago

"27 Years Making Good Instruments"

SCIENCE QUESTIONS.

CONDUCTED BY FRANKLIN T. JONES,
The White Motor Company, Cleveland, Ohio.
Please address all communications to Franklin T. Tones, 10109 Wilbur Avenue, S. E., Cleveland, Ohio.

QUESTIONS AND PROBLEMS FOR SOLUTION AND DISCUSSION.

487. *Proposed by B. G. Spracklin, B. A., B. Sc., Instructor in Chemistry, Baron Byng High School, Montreal, P. Q.*

Supposing the specific gravity of copper is 8.8, a solid piece would, of course, sink in water; but, by making a hollow ball of the right size, one could get it to float just as an ordinary tin pan floats on water.

If the ball were made of 3 cu. inches of copper (*a*) how large would it need to be in order that it might float, and (*b*) how large that it might float half out of water?

488. *Proposed by B. G. Spracklin from an examination paper set by Prof. John Waddell, Ph. D., D. Sc.*

If ice floats with 1/10 its volume above the surface of the water, but in alcohol neither rises nor sinks no matter where placed below the surface of the liquid, what is the specific gravity of the alcohol?

489. *Proposed by John C. Packard, Brookline, Mass.*

Why do the laths "show through" as dark stains on an old plaster ceiling?

EXAMINATION PAPERS REPUBLISHED.

Question 479 first published in December, 1926, is repeated below. The 1926 College Entrance Board Examination paper in Botany was published on page 1004 of SCHOOL SCIENCE AND MATHEMATICS, Dec., 1926. The 1906 paper was inadvertently omitted. It is printed below.

479. *How much difference exists between the teaching of botany today and twenty years ago?*

a. Subject matter;
b. Laboratory work;
c. Method of conducting classes;
d. Demonstrations;
e. Examinations and examination questions;
f. Applicability to daily life;
g. Distinct improvements;
h. Retrogressions—If worse, specify exactly how and where;
k. How make improvements?

The above questions offer opportunity for the readers of this department and for all who are deeply interested in the improvement of science teaching in general to express either their satisfaction or dissatisfaction with present conditions.

COMPLETE ANSWERS ARE NOT EXPECTED.

Send in your ideas on any one or more of the separate questions.
Please be prompt. Do it now!

COLLEGE ENTRANCE EXAMINATION BOARD.

MONDAY, JUNE 18, 1906, 3:45-5:45 P. M.

BOTANY.

Answer any nine of the following questions. In this examination 37 counts will be based upon the laboratory note book, and 63 upon the following questions.

1. Briefly describe, sketch and name the parts of some complete flower, telling what the function of each part is.
2. Show in cross-section the structure of an ordinary leaf-blade, naming the different structures.

3. For what special functions other than the ordinary and typical ones may the root, stem and leaf become modified? What are the names of the resultant structures?
4. What do you know of the structure of a living plant cell?
5. What raw materials are absorbed into a green plant? From what sources? By what organs? What use is made of these raw materials?
6. What is transpiration and what does it mean to the plant? How is its amount determined by experiment? Under what conditions does the amount become more or less?
7. What different methods of fertilization in the plant kingdom do you know? Describe each with sketches.
8. Describe the life history of some pteridophyte.
9. What are the differences between monocotyledons and dicotyledons? Name four families and twelve species of each group.
10. What are the leading natural groups into which the plant kingdom is classified? Give the leading characteristics of each group.
11. Name five typical algae and five fungi, adding a few words descriptive of each.
12. What do you understand by (a) ecology, (b) physiology? Illustrate by brief descriptions of typical examples other than any mentioned in this paper.

DIRECTORY OF SCIENCE AND MATHEMATICS SOCIETIES

American Association for the Advancement of Science and Associated Societies—President, Arthur A. Noyes, California Institute of Technology, Pasadena, California; Permanent Secretary, Burton E. Livingston, Johns Hopkins University, Baltimore, Md. (Association mail address: Smithsonian Institution Building, Washington, D. C.) Treasurer, John L. Wirt, Carnegie Institution of Washington, Washington, D. C.; General Secretary, W. J. Humphreys, U. S. Weather Bureau, Washington, D. C.

American Association for Medical Progress—President, George Murnane, New York City; Secretary, Edward Wigglesworth, Director of Boston Museum of Natural History; Treasurer, Frederick K. Barbour, New York City.

American Astronomical Society—President, George C. Comstock, Beloit, Wisconsin; Vice-Presidents, S. A. Mitchell, University of Virginia, and A. O. Leuschner, Berkeley, California; Secretary, Joel Stebbins, Madison, Wisconsin; Treasurer, Benjamin Boss, Albany, N. Y.

American Physical Society—President Karl T. Compton, Princeton University; Vice-President, Henry G. Gale, University of Chicago; Secretary, Harold W. Webb, Columbia University; Treasurer, George B. Pegram, Columbia University.

Association of Science Teachers of the Middle States and Maryland—President, Dr. Charles E. Dull, Newark, N. J.; Vice-President, Dr. M. Louise Nichols, Philadelphia, Pa.; Secretary-Treasurer, Miss Elizabeth W. Towle, Bryn Mawr, Pa.

Central Association of Science and Mathematics Teachers—President, E. R. Breslich, The School of Education, The University of Chicago, Chicago, Ill.; Vice-President, W. F. Roecker, Boys' Technical High School, Milwaukee, Wisconsin; Secretary, Winnafred Shepard, Proviso Township High School, Maywood, Ill.; Corresponding Secretary, Margery Stewart, New Trier High School, Kenilworth, Ill.; Treasurer, W. G. Gingery, Shortridge High School, Indianapolis, Indiana.

Eastern Association of Physics Teachers—President Frank A, Sheldon, Noble & Greenough School, Dedham, Mass.; Vice-President, Elliott P. Frazier, English High School, Boston, Mass.; Secretary, John B. Merrill, High School, East Boston, Mass.; Treasurer, William F. Rice, Public Latin School, Boston, Mass.

History of Science Society—President, Dr. David Eugene Smith, Columbia University; Vice Presidents, Dr. Edgar F. Smith, University

of Pennsylvania, and Dr. Lynn Thorndike, Columbia University; Recording Secretary, Dr. C. A. Browne, U. S. Bureau of Chemistry; Treasurer and Corresponding Secretary, Mr. Frederick E. Brasch, Library of Congress.

ILLINOIS STATE ACADEMY OF SCIENCE—President, W. N. Clute, Editor "The American Botanist," Joliet; First Vice President, Mary M. Steagall, Southern Illinois State Teachers College, Carbondale; Second Vice President, C. E. Spicer. Joliet High School, Joliet; Secretary, Lyell J. Thomas, University of Illinois, Urbana; Treasurer, W. B. McDougall, University of Illinois, Urbana.

INDIANA ACADEMY OF SCIENCE—President, Frank B. Wade, Shortridge High School; Vice President, F. J. Breeze, Ball Teachers College, Muncie; Secretary, Ray C. Friesner, Butler College, Indianapolis; Assistant Secretary, W. P. Morgan, Indiana Central College, Indianapolis; Treasurer, M. W. Lyon, Jr., 214 Laporte Avenue, South Bend.

IOWA ASSOCIATION OF SCIENCE TEACHERS—President, John R. Coulson, East Waterloo High School; Vice President, F. E. Goodell, West Des Moines High School; Secretary-Treasurer, Frances Church, East Des Moines High School.

LANGLEY ASSOCIATION OF SCIENCE TEACHERS—President, Charles A. Gorgas, Peabody High School, Pittsburg, Pa.; Secretary, Frank W. Murphy, Oliver High School, Pittsburg, Pa.

MATHEMATICAL ASSOCIATION OF AMERICA—President, Walter B. Ford; Vice Presidents, A. J. Kempner, Clara E. Smith; Secretary-Treasurer, W. D. Cairns; Office of the Secretary-Treasurer, Oberlin, Ohio.

METRIC ASSOCIATION—President, George F. Kunz; First Vice President, Walter Wood; Second Vice President, Wm. Jay Schieffelin; Third Vice President, Eugene C. Bingham; Secretary, Howard Richards; Treasurer, Frederic L. Roberts.

NEW ENGLAND ASSOCIATION OF CHEMISTRY TEACHERS—President, Alfred M. Butler, High School of Practical Arts, Boston, Massachusetts; Vice President, Elwin Damon, Keene High School, Keene, N. H.; Secretary, John H. Card, English High School, Boston 18, Massachusetts; Assistant Secretary, Octavia Chapin, Malden High School, Malden, Massachusetts; Treasurer, Shipley W. Ricker, Woburn High School, Woburn, Massachusetts.

PHYSICS CLUB OF NEW YORK—President, Howard W. Mott, Stuyvesant High School, New York City; Vice President, Dr. H. H. Sheldon, New York University, Washington Square East, New York City; Secretary, Carl J. Hunkins, South Side High School, Newark, N. J.; Treasurer, Allen C. Hutchinson, South Side High School, Newark, N. J.

SOUTHERN CALIFORNIA SCIENCE AND MATHEMATICS ASSOCIATION—President, Dr. J. E. Bell, California Institute of Technology, Pasadena; Vice President, E. A. Just, Polytechnic High School, Long Beach; Secretary-Treasurer, Deca Lodwick, Polytechnic High School, Long Beach.

ARTICLES IN CURRENT PERIODICALS.

American Journal of Botany, February, Brooklyn Botanic Garden at Prince and Lemon Sts., Lancaster, Pa., $7.00 a year, 75 cents a copy. The Chromosomes of Zea Mays, Emma L. Fisk. A Study of meiosis in Ranunculus acris, Helen Sorokin. Respiration in Corn with Special Reference to Catalase, C. W. Lantz.

American Mathematical Monthly, February, Menasha, Wis., $5.00 a year, 60 cents a copy. Successive Generalizations in the Theory of Numbers, E. T. Bell, California Institute of Technology. The Value of Mathematical Models and Figures, Arnold Emch, University of Illinois. On Three Interesting Terms Relating to Area, Solomon Gandz, Rabbi Isaac Elchanan Theological Seminary, New York. On the Least Multiple of an Integer Expressible as a Definite Quadratic Form, H. S. Vandiver, University of Texas.

Education, February, The Palmer Co., Boston, $4.00 a year, 40 cents a copy. Education and Life, Professor Max Schoen, Department of Education and Psychology, Carnegie Institute of Psychology, Schenley Park, Pittsburgh, Pa. Making History Interesting to High School Students, Walter C. Pankratz, Student, The University of Chicago. A Citizenship Rating Scale, Superintendent Edward L. Hill, Dighton, Mass. What is the Matter with the Teaching Profession? Mildred V. W. Patterson, Rensselaer, N. Y.

Journal of Geography, February, 2249 Calumet Ave., Chicago, Ill., $2.50 a year, 35 cents a copy. Geographic Regions of the Philippine Islands, George S. Case, Columbia University. Gateways of the World: A Geography Pageant, Mary J. Washington, Indiana Avenue School, Atlantic City, New Jersey. Background for the Study of Industrial Geography, Selma A. Hult and Nancy M. Waters, Whittier Junior High School, Lincoln, Nebraska.

Mathematics Teacher, February, National Council of Teachers of Mathematics, New York, $2.00 a year (eight numbers), 40 cents a copy. General Mathematics, Professor Raleigh Schorling, University of Michigan. Rigor versus Expediency in the Proof of Locus Originals, Elmer R. Bowker, Public Latin School, Boston, Mass. The Arithmetical Productiveness of Utilitarian, Social and Scientific Ideals: Viewed Historically, G. W. Myers, The University of Chicago. The Use of Problems in Teaching Elementary Algebra, E. H. Taylor, Eastern Illinois State Teachers College, Charleston, Ill. The Middle of the Road, W. A. Snyder, Head of Mathematics Department, New Trier Township High School, Winnetka, Ill.

National Geographic Magazine, March, Washington, D. C., $3.50 a year, 50 cents a copy. Ireland: The Rock Whence I Was Hewn, Donn Byrne. The Green Mountain State, Herbert Corey.

Photo-Era Magazine, February, Wolfeboro, New Hampshire, $2.50 a year, 25 cents a copy. Convenient Photo-Finishing, John Swayze, Jr. Photographing the Denizens of the Zoo, Arthur H. Farrow. Practical Kinematography, Chapter XVIII, Herbert C. McKay. How Shall I Set the Shutter? B. H. Jacobs.

Popular Astronomy, February, Northfield, Minn., $4.00 a year, 45 cents a copy. A Ring Nebula (Dark) in Cygnus, D. W. Morehouse. Report on Mars, No. 38, William H. Pickering.

School Review, February, The University of Chicago Press, $2.50 a year, 30 cents a copy. The Program of Studies in Seventy-eight Junior High School Centers, R. M. Tryon, H. L. Smith and Allan F. Rood. A Study of the Causes of High School Failures, C. A. Gardner, North Side High School, Forth Worth, Texas. Experiments in Democracy, Joseph G. Masters, Central High School, Omaha, Nebraska. Low I. Q.'s in the High School, Anna E. Biddle, South Philadelphia High School for Girls, Philadelphia.

Science, February 11, Grand Central Terminal, New York City, $6.00 a year, 15 cents a single copy. A Mathematical Critique of Some Physical Theories, George D. Birkhoff, Harvard University. February 18, Infra-red Spectroscopy, Professor H. M. Randall, Department of Physics, University of Michigan. Scientific Service that the National Forests Might be Rendering, Willard G. Van Name. February 25, The Smithsonian Institution: Parent of American Science, William Howard Taft, Chancellor of the Smithsonian Institution. Underlying Factors in the Confusion in Zoological Nomenclature with a Definite Practical Suggestion for the Future, C. W. Stiles, U. S. Public Health Service.

Scientific American, March, New York, $4.00 a year, 35 cents a copy. The Signal Corps of the Movies, A. P. Peck. The Simplest Element of All, Hugh S. Taylor, Professor of Physical Chemistry, Princeton University. Micro Motion Pictures, Heinz Rosenberger, The Rockefeller Institute for Medical Research, New York. The Month in Medical Science, Morris Fishbein, M. D., Editor of the Journal of the American Medical Association and of Hygeia. Psalmist's Spring to Supply Jerusalem with Water, Harold J. Shepstone.

LEITZ

Triple Divisible Objective "Trio" No. 22003a.

It combines at one price: the cost of three objectives and a triple nosepiece

Section 1: when used alone has 19 mm. focus and 7.5X initial magnification; using with it Oculars 4X to 12X results in a combined magnification of 30X to 90X.

Section 2: if used together with section 1 has 8 mm. focus and 20x initial magnification; using with it Oculars 4X to 12X results in a combined magnification of 80X to 240X.

Section 3: if used together with sections 1 and 2 has 4mm. focus and 38X initial magnification; using with it Oculars 4X to 12X results in a combined magnification of 152X to 456X.

For reasons of economy and convenience, the Leitz Works have constructed a *Triple Divisible Objective "Trio"* which serves first *to similar capacity as three objectives* of different magnifying power and secondly, *as a triple nosepiece.* Inasmuch as this objective is used in three sections, each set in a different mounting on separate hinge, one can successively use one section alone, two together or the three sections combined.

Magnifications from 30X to 456X are considered fully sufficient for elementary microscopical studies and in comparing the prices of microscopical equipments including the triple divisible objective "Trio" *one will readily conceive the economic advantages derived through the purchase of the "Trio" objective.*

This objective can be used on any microscope, regardless of make.

Cat. No. 22003a
Code Word:ABAAZ

Leitz Triple Divisible Objective "Trio" $15.00
Institutional Discount: 10%

E. LEITZ, Inc.

60 East Tenth Street **New York, N. Y.**

Agents:

Pacific Coast States: Spindler & Sauppe, offices at San Francisco and Los Angeles, Calif.
Canada: The J. F. Hartz Co., Ltd. Toronto, Can.
Philippine Islands: Botica de Santa Cruz, Manila, P. I., Cuba Antiga & Co., Havana, Cuba.

Scientific Monthly, March, The Science Press, New York, $5.00 a year, 50 cents a copy. The Contribution of Biology and its Applications, C. E. McClung, University of Pennsylvania. Science, the Declaration, Democracy, by Dr. J. McKeen Cattell, formerly of Columbia University. America's Opportunity in Chemistry, William A. Noyes, University of Illinois. Engineering and the Nation, Dr. D. S. Kimball, Dean of the College of Engineering, Cornell University. The Atmosphere: Origin and Composition, Dr. W. J. Humphreys, U. S. Weather Bureau.

Torreya, January-February, 1927, 8 West King St., Lancaster, Pa., $1.00 a year, 30 cents a copy. A Six-Hour Cross-Section of the Vegetation of Southern Ontario, Roland M. Harper. A Note on the Interrupted Fern, N. M. Grier. The Cat Tail, Typha Angustifolia, in Utah, J. Arthur Harris.

BOOKS RECEIVED.

A Laboratory Manual for General Botany, Part I by David Potter, M. Sc., Instructor in Botany, Clark University, Worcester, Mass. Paper. Pages 145. 22 x 15 cm. 1927. The Bruce Publishing Company, Milwaukee, Wisconsin. Price 96 cents. Part II, paper. Pages 129. 27 x 20.5 cm. 1927. Price $1.08.

A Second Geometry by J. Davidson, M. A., Mathematical Master at Aberdeen Grammar School and A. J. Pressland, M. A., formerly scholar of St. John's College, Cambridge. Cloth. 128 pages. 18.5 x 12 cm. 1926. Oxford University Press, American Branch, New York. Price 85 cents.

Diagnostic Tests in the Fundamental Operations of Arithmetic and in Problem Solving for Grades VII, VIII and IX. Form A by W. C. Reavis and E. R. Breslich, School of Education, The University of Chicago. Paper. 15 pages. 23 x 15 cm. 1927. The University of Chicago. Form B, paper. 15 pages. 23 x 15 cm. 1927. Forms A and B, paper. 5 pages, 23 x 15 cm. 1927.

An Outline and Teachers' Manual for the Study of Maine Geography by Charles S. Preble, Department of Geography, Farmington State Normal School, Maine. Paper. 46 pages. 23 x 15 cm. 1927. Farmington State Normal School.

Junior High School Mathematics, Seventh School Year by Harry C. Barber, Head of the Mathematics Department in the Charlestown High School, Boston, assisted by Helen M. Connelly, Rice and Quincy Schools, Boston and Elsie V. Karlson, Agassiz School, Boston. Cloth. Pages xiv+231. 19 x 12 cm. 1927. Houghton Mifflin Company. Price 92 cents.

Games and Sports in British Schools and Universities, Bulletin number eighteen. The Carnegie Foundation for the Advancement of Teaching by Howard J. Savage. Paper. 252 pages. 18.5 x 25.5 cm. 1927. Free on application. The Carnegie Foundation for the Advancement of Teaching, 522 Fifth Avenue, New York City.

The Uredinales or Rusts of Connecticut and the Other New England States, Bulletin No. 36. State Geological and Natural History Survey, by Willis Roberts Hunt, Ph. D., Scientific Assistant in Botany, Connecticut Agricultural Experiment Station. Paper. 198 pages. 23 x 14.5 cm. 1926. Published by the State at Hartford. Price $1.00.

Psychological Analysis of the Fundamentals of Arithmetic by Charles Hubbard Judd. Paper. Pages x + 122. 23.5 x 16.5 cm. 1927. The University of Chicago, Chicago, Illinois. Price $1.00.

Quantitative Analysis by Stephen Popoff, Ph. D., Assistant Professor and Head of Analytical Chemistry, State University of Iowa. Second edition. Cloth. Pages xix+559. 23 x 15 cm. 1927. P. Blakiston's Son & Co. Price $4.00.

Problems of Modern Physics by H. A. Lorentz, Professor in the University of Leiden and edited by H. Bateman, Professor in the California Institute of Technology. Cloth. Pages vi+312. 20.5 x 13.5 cm. 1927. Ginn and Company. Price $3.60.

Basic Material for a Pharmaceutical Curriculum prepared under the Direction of W. W. Charters, University of Pittsburgh, A. B. Lemon, University of Buffalo, Leon M. Monell, University of Buffalo. Cloth. Pages xiii+366. 23 x 14.5 cm. 1927. McGraw-Hill Book Company, Inc., New York, 370 Seventh Avenue. Price $4.00.

Physics for Colleges by H. Horton Sheldon, Ph. D., Associate Professor and Chairman of the Department of Physics, Washington Square College, New York University, C. V. Kent, Ph. D., Associate Professor of Physics, University of Kansas, Carl W. Miller, Ph. D., Assistant Professor of Physics, Brown University, Robert F. Paton, Ph. D., Associate Professor of Physics, University of Illinois. Cloth. Pages vi+655. 21.5 x 13.5 cm. 1926. D. Van Nostrand Company, 8 Warren Street, New York.

Tests and Measurements in High School Instruction by G. M. Ruch, Professor of Education, University of California and George D. Stoddard, Assistant Professor of Psychology and Education, State University of Iowa. Cloth. Pages xix+381. 19.5 x 13 cm. 1927. World Book Company, Yonkers-on-Hudson, New York. Price $2.20.

BOOK REVIEWS.

General High School Mathematics, Book II, by D. E. Smith, Professor of Mathematics, Teachers College, Columbia University, J. A. Foberg, Director of Mathematics, Department of Public Instruction, Pennsylvania, and W. D. Reeve, Associate Professor of Mathematics, Teachers College, Columbia University. Pages viii+472. 14x19.5cm. 1926. Boston, Ginn. $1.60.

This is the second of two books designed primarily for schools desiring to give a two-year course in general mathematics.

The authors hold that experience has shown that the most satisfactory division of emphasis in a general mathematics course is to make the work of the first year center about algebra as the chief feature, combining it, whenever a natural link is offered with computation, intuitive geometry, and the elementary principles of trigonometry.

This second book makes demonstrative geometry its central feature for the year's work. There are numerous "originals," many of which contain practical applications. At the end of each chapter one finds a test in which some of the exercises are of the objective type. One also finds reviews which cover not only the work of the year but of the preceding year. J. M. Kinney.

Arithmetic for Teacher-training Classes, by E. H. Taylor, Ph.D., Head of the Department of Mathematics, Eastern Illinois State Teachers College. Pages vii+344. 13x19.5cm. 1926. New York, Holt.

This book is designed to give students who are preparing to teach arithmetic a teacher's view of the subject. It aims to give a mastery of arithmetic processes and at the same time to point out the aims of arithmetic instruction together with the proper choice of materials to attain them.

Numerous references conclude each chapter on a fundamental process.

J. M. Kinney.

Standard Service Arithmetics, Book Two, for Grade 4, by F. B. Knight, University of Iowa, J. W. Studebaker, Superintendent of Schools, Des Moines, Iowa, and G. M. Ruch, University of California. 13.5x19cm. Pages xiv+456. $0.80. 1927. Chicago, Scott, Foresman and Company.

This is the third book of the Knight-Studebaker-Ruch arithmetic series to be published, Books One (3rd grade) and Three (5th and 6th grades) having preceded it.

This book, like its predecessors, is a work of science and art. It seems to the writer that children provided with this book would thoroughly enjoy their work in arithmetic.

Some of the features of the book are the following:

(1) The customary review of third grade work is replaced by diagnostic inventory tests of third grade essentials and ideas. For the

benefit of those pupils who need further drill on third grade work self-help study and practice exercises have been provided in the appendix.

(2) New topics are developed gradually and in detail.

(3) Drills and reviews have been carefully placed.

(4) Ingenuous motivating devices have been employed.

(5) Provision has been made for securing an "active, critical, social, and self-reliant attitude toward the learning of arithmetic."

(6) Lessons are planned to give the child an insight into problem analysis.

(7) Provision is made for systematic measurement and recording of achievement through self-testing drills, problem scales, and other standardized material. J. M. Kinney.

Palladin's Plant Physiology, by the late Vladimir I. Palladin, Professor in the University of Leningrad, with additions and editorial notes by Burton E. Livingston, Ph.D., Professor of Plant Physiology, Johns Hopkins University. Authorized Edition in English. Third American edition based on the sixth and seventh Russian editions. 8vo. xxxv+360 pages, with 174 illustrations. Published by P. Blakiston's Son & Co. 1926. Cost $4.00.

This text book of Physiology has met with great success since its publication, having gone through seven Russian editions and having been translated into German and English, of which this is the third edition. Its success lies in its great readability and the thoroughness of its treatment of the subject. It is a book that beginning college students can read and is yet useful for the advanced workers. No critical analysis of such a book can be given for this publication, nor is it needed. Secondary school teachers of botany and biology will appreciate the value to them of an authoritative work on the subject in usable form, up to date in its facts and treatment. W. W.

Elements of Physics, by Robert Andrews Millikan, Ph. D., Sc. D., Director of the Norman Bridge Laboratory of Physics, Pasadena, Cal., Henry Gordon Gale, Ph. D., Professor of Physics in the University of Chicago, and Willard R. Pyle, B. S., Head of the Department of Physics, Morris High School, New York City. Cloth. Pages xiii+509. 19.5x12.5 cm. 1927. Ginn & Company, Chicago.

"To present elementary physics in such a way as to stimulate the pupil to do some thinking on his own account about the hows and whys of the physical world in which he lives" is the aim of the authors. In order to realize this aim every device of the teacher, of the writer and of the artist is employed to interest the pupil; not to create merely a superficial interest but an insatiable desire to understand the principles of elementary physics and their applications. The book stands as evidence that the authors and publishers have worked in perfect harmony to produce a better text than has previously been offered to the schools.

The good points of former Millikan and Gale textbooks have been retained. The changes consist of (1) the substitution of problems and questions better adapted to the high school student's mind for some of the more difficult ones previously used; (2) more and better illustrations; (3) summaries of chapters and subdivisions; (4) addition of new developments in the subject such as structure of atoms, atomic energy, and cosmic rays in theoretical physics, and new types of airplanes, Diesel engines, farm tractors and radio apparatus in applied physics.

The incidental picture course in the history of physics which made the previous book so attractive has been enlarged. Ninety-nine full page pictures of scientists, modern inventions and industrial applications with interesting descriptions of each are interspersed in appropriate places. The paper and type are well selected for elimination of glare and eye strain.

In reading over some sections one experiences a slight disappointment in finding that the recent but well-established theories of atomic structure and electronic orbits have not been fully utilized in some of the

explanations. An example of this is found in the discussion of the action of a voltaic cell on page 296 where the text says: "When these repelled hydrogen ions reach the copper plate, some of them give up their charges to it and then collect as bubbles of hydrogen gas. It is n this way that we account for the positive charge which we found on the copper plate in the experiment of Section 301." G. W. W.

Freshman Hygiene, by Raymond C. Bull, A.B., M.D., Director of Student Health Service, Lehigh University, and Stanley Thomas, M.S., M.A., Associate Professor of Bacteriology, Lehigh University. Cloth. Pages x+288. 13x20½cm. 74 illustrations. 1926. J. B. Lippincott Co. Price $2.00.

The first year in college a student learns many things not taught in his regular classes. This may be the first time he has ever been away from home, the first time he has had to assume complete responsibility for the care of his health, for the efficient use of his time, for his social activities, and for the selection of new friends. To assist the first year college student in these perplexing situations is the aim of the authors of this book.

The material is so arranged that it may be used as a text book for classes in hygiene, but the clear and interesting method of presentation practically assure that it will be read if placed in the student's hands. Personal hygiene makes up about two-thirds of the book. The processes of the body most influential in determining health are discussed from the student's viewpoint and in a manner that appeals to his sense of reason and justice. Anatomy and physiology are introduced where needed to serve the main purpose of guiding the student in correct living. Problems of social hygiene are discussed with scientific accuracy but in a method that will promote serious consideration of the consequences of the violation of natural laws, and stimulate high ideals of life and character. G. W. W.

X-ray photographs of Harvard freshmen, taken this year for the first time, showed that only 36 of the 842 men had any physical defects at all, and these were of a minor nature. As to posture, silhouetteographs showed that only 35 men carried themselves well enough to be rated in the "A" groups, 300 were graded "B," 375 "C," and 124 "D." These findings are slightly better than the statistics of the class of 1929.